Fourth Biennial Report

OF THE

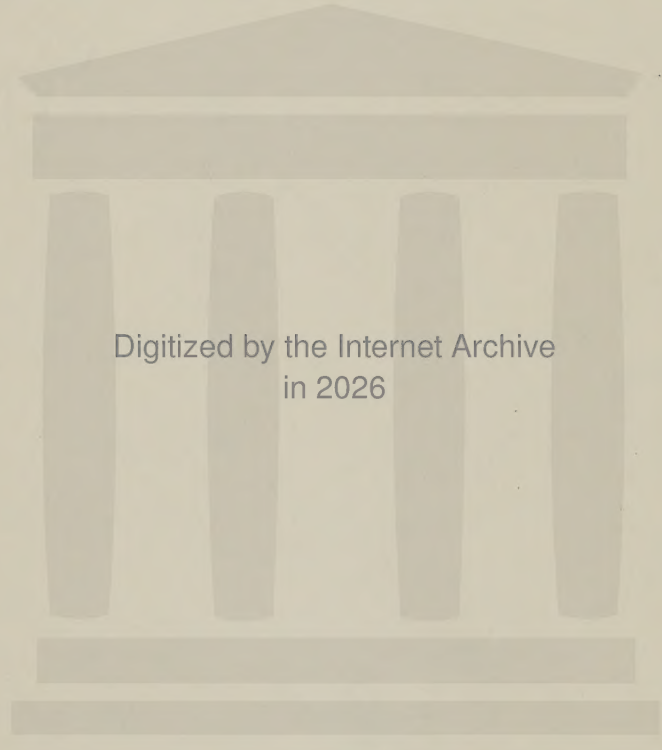
Department of Engineering

OF THE

State of California

DECEMBER 1, 1912, TO NOVEMBER 30, 1914

CALIFORNIA
STATE PRINTING OFFICE
1914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LETTER OF TRANSMITTAL.

November 30, 1914.

Honorable HIRAM W. JOHNSON,
Governor of the State of California.

SIR: Pursuant to the provisions of an act of the Legislature approved March 11, 1907 (Chapter 183, Statutes 1907), I respectfully submit herewith for your consideration the fourth biennial report of the operations of the Department of Engineering for the period from December 1, 1912, to November 30, 1914, inclusive.

Respectfully,

W. F. McCLURE,
State Engineer.

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BIENNIAL REPORT OF THE DEPARTMENT OF ENGINEERING.

INTRODUCTION.

In presenting this, the fourth biennial report of the Department of Engineering, it is deemed proper to invite special attention to certain matters relating to the work as set forth herein.

Comparatively few people, it is believed, have comprehensive understanding as to the extent of the field covered by the work of this Department, nor of the amount of public moneys the expenditure of which is placed by law under its direction.

It is believed that a perusal of this report of the various and extensive activities of the Department will convince the reader that to accomplish its full purposes in all the lines delegated to it, every facility should be provided for transacting its business promptly with the public and comfortably to its members and employees.

The Department has never had adequate quarters. Its office force is crowded into small, poorly lighted rooms without proper ventilation, and never in its seven years of existence has the Department been all housed in one building. The executive and architectural divisions have been occupying rooms on four floors of the Capitol, while two divisions were placed in downtown office buildings a block or more separated and three or four blocks from the Capitol.

These matters are not mentioned in the way of criticism, for the writer fully appreciates that those whose duty it is to provide quarters for all State offices have done their utmost, but rather to emphasize remarks to follow.

In the report two years ago, in commenting upon those adverse conditions it was remarked:

> The designing of public works which falls to the Department requires diligence, skill, experience and the highest order of professional integrity, and to command the services of men possessing these qualifications the Department must be in a position to offer comfortable quarters, congenial surrounding and remuneration commensurate with the character of service sought to be obtained.

The volume and character of the work accomplished, as set forth in the pages of this report, performed as it was under the conditions described, testify to the loyalty and efficiency of the officers and employees who have accomplished it.

The Department has occupied a large number of rooms in the Capitol designed for the use of committees of the legislature.

In the interim between sessions this arrangement could obtain, but with the approach of each session these rooms had to be surrendered, and the resulting congestion of the Departments in the remaining rooms entailed much discomfort.

The Superintendent of the Capitol and the Board of Control have secured offices in the Forum building, Ninth and K streets, for the Department of Engineering. The Highway Division has occupied rooms in that building for more than three years. All of the Department now in the Capitol, excepting the Motor Vehicle Division, will be moved, as also the Flood Control Division, which is now in the Nicolaus building, so that the Department will be more nearly united in location of its several parts than ever before.

This arrangement will probably continue until new office building authorized by the last legislature shall be constructed.

While it is anticipated that considerable inconvenience will result from the Department being so far away from the other departments of the State with which it has close relations, it is felt that the relief from the cramped conditions under which it has worked so long will be a great comfort.

Attention is invited to the summary of work executed by the Architectural Division, wherein is shown that the architectural service, including inspection of construction for buildings costing nearly one and one-fourth million dollars, was 5¼ per cent. In this connection it is well, too, to consider that the plans prepared by the Department are more complete in detail than ever were furnished for public buildings before the time this Department began making them.

Attention is also directed to the discussion of the work of the purchasing office, and the remarkable growth of business accruing to that section.

Under hydroeconomics the discussion of matters pertaining to flood control and particularly the demands for State assistance coming from sufferers from ravages of floods from streams other than the Sacramento and San Joaquin rivers, is commended for consideration, as well, also, as the desirability of extending the jurisdiction of the State Reclamation Board, by enlarging the Sacramento and San Joaquin Drainage District.

The results of research conducted by co-operation between the Department and the several branches of the Federal government are discussed at some length, and it is earnestly recommended that appropriations therefor be continued. Particular attention is invited to the research conducted in the field of irrigation inquiry in which it is believed much valuable information is set out.

In the matter of river work, every effort has been used to conserve the funds and accomplish effective work, full exposé of which is set forth under the appropriate headings.

The question of canalization and canals has been under investigation by the Department, but it is not deemed proper to burden this report with a discussion of the subject until the data shall be amplified by physical examination of probable routes of inland water traffic. This it has not been possible to do without funds, but the Department is prepared to show the desirability of further prosecution of studies along the lines indicated.

The benefits that have accrued to the State from greatly improved maintenance work on the State roads due to funds obtained from the motor vehicle license, is set out under the heading of State roads. These benefits are made evident by the marked increase in travel over those roads as shown by comparison of the census of 1913 and 1914, appearing in tabular form.

Attention is called to the growth and expansion of business transacted by the Department of Engineering since it was first established without a commensurate increase being made in the contingent fund allotted for the use of the Department. This is a matter that it is earnestly hoped will not be lost sight of in making appropriations for the support of the Department.

The cordial relations sustained between the Department and the various branches of the State government, the several institutions and the many branches of the Federal government with which co-operative work has been conducted, has been a source of personal satisfaction and the State Engineer takes this opportunity of acknowledging the many courtesies received at the hands of all with whom dealings have been had.

BIENNIAL REPORT OF DEPARTMENT OF ENGINEERING.

HISTORY.

Although the organization of the California State Department of Engineering dates back only to 1907, the advisability of placing certain governmental functions under scientific direction was early realized by the pioneers who founded this state on the Pacific shore.

We of today are wont to think of the early days of California as given over to a mad rush to the gold mines, without a thought being given to other lines of endeavor than that of digging for the yellow metal. Perusal of official records, however, discovers that the sturdy builders who laid the foundation for this commonwealth had prophetic vision to see the vast opportunity offered by the fertile lands and salubrious climate for the establishment of homes and the expansion of commerce and all the concomitant activities of a populous and busy state.

The first legislature was convened at San Jose in December, 1849, and continued its session into the early months of the succeeding year.

In January, 1850—eight months before California was admitted to the union of states—a bill was enacted and became a law, creating the office of Surveyor General and defining his duties. In addition to his other duties prescribed in general terms he was specifically directed to make a scientific survey of the boundaries of the state; make an accurate map of the state; survey and fix the boundaries and corners of counties. He was made a member of a Commission of Internal Improvement and ex officio chief engineer of the Commission, and as such he was required to make annual report showing:

> Progress of surveys and of state map: Plans and suggestions for the improvement of the internal navigation of the state and for the construction and improvement of roads, turnpikes, railroads, canals and aqueducts; also plans and suggestions for the planting, preservation and increase of forests of lumber trees, for the draining of marshes, prevention of overflows and the irrigation of arable lands by means of reservoirs, canals, artesian wells or otherwise; prepare statistics of state lands and of lands adapted to tillage and grazing; number of horses, cattle and other stock, and their value; amount of farm produce of all kinds, with his views as to presence and cause and the remedies for diseases that injure such products; quantities of all mineral lands and quantities and value of mineral products.

A perusal of the schedule of duties prescribed for the Surveyor General shows that the question of the conservation of natural resources so actively advocated by the progressive elements in political and industrial activities today is not a new fad. More than sixty years ago the lawgivers of California directed research to be made along many of the lines now being pursued. And had the program laid down in 1849

and 1850 been carried forward by placing its execution in the hands of competent men, supported by adequate appropriations, what a wealth of information would have been acquired and what a difference would have resulted in the magnitude and stability of the state's industrial development! But without sufficient funds, and often with men in office who had no higher aims nor better conception of the duties imposed by the law than shown in the report of an early incumbent, the elaborate plans laid by the prescient minds of the pioneer builders of the commonwealth fell far short of realization.

To repeat: Had energetic, broad-minded and public-spirited men been entrusted with the duties enumerated, and given adequate funds to conduct research and for carrying out such projects as would have been evolved, many of the problems of economic development with which we are struggling today would have been solved and our people would now be reaping the benefits.

But unfortunately the office to which these functions were delegated was a political one, and was often occupied by men more intent upon rendering service to their party than to the state.

When, perchance, a man was elected who was inspired by loyalty to the state to devote his energies to the tasks enjoined upon him by the law, he was hampered by the failure of the legislature to provide adequate funds to put into being any of the public projects deemed so desirable by the first legislature above described.

With the growth of the state and its needs becoming more apparent the demand for action became insistent.

As new industries were inaugurated and old ones expanded, many of the duties imposed upon the Surveyor General by the statute quoted were transferred to others. Research into mineral resources was delegated to a State Geologist and later conducted by a Mining Bureau and State Mineralogist. Matters pertaining to agriculture and horticulture were, as now, handled by the Agricultural Society and Horticultural Commissioner. Problems in forestry are referred to the Board of Forestry. And so with other subjects requiring technical training for their administration, all being assigned to officers, boards, or commissions specially fitted or purposely organized for the particular work required.

As time went on some industries became antagonistic to others. Hydraulic mining in the mountains continued unabated. Farmers in the valley whose crops were destroyed by floods claimed the disasters were augmented, if not caused, by the filling of the river channels with detritus from the mines. Navigators on the streams complained that their business was injured from the same cause. Anti-debris associations were formed to attempt the prevention of mining. Miners'

protective associations were organized to resist what the miners considered encroachments upon their rights.

Other antagonisms arose. The first settlers were attracted to the moist lands along the banks of the streams, where the perennial inundations caused the native grasses to grow luxuriantly, furnishing abundant feed for stock without cost to the settler. Later other settlers occupied the lands remote from the streams, but found it necessary to bring water in canals from the rivers to irrigate their lands and cause them to produce remunerative crops. The man on the banks, at first indifferent, soon discovered that his lands were, or might become, deprived of their natural source of fertility and began to quarrel with the neighbor who had diverted water from the stream above him. Strife ensued between the appropriator and riparian claimant, as well as between the valley farmer and the miner. Armed contention became frequent and bloodshed followed.

The existing laws failing to define the relative rights of contending parties and both sides in each controversy setting up claims that could not be ignored, it became necessary to create an agency to conduct a line of research to gather facts—scientific facts—from which to define conditions, determine causes and prescribe remedies.

More than a quarter of a century after the first legislature had directed the matters to be done as enumerated in the beginning of this chapter, the legislature of 1878 again took up the questions, and by an act approved March 28th, entitled "An act to provide a system of irrigation, promote rapid drainage and improve the navigation of the Sacramento and San Joaquin rivers," inaugurated the first organized effort along the lines so long considered.

This act created the office of State Engineer and directed him to make investigations, to ascertain facts and express opinions concerning the water-carrying capacity of the Sacramento and San Joaquin rivers in the different sections which are liable to overflow; whether their capacities could be increased and by what means, and the cost thereof; the maximum flood flow and whether works could be devised to enable the streams to carry it; to ascertain changes in the river beds, if any, their cause, and legislation necessary to correct and arrest such changes; area of arable lands and quantity of water available for irrigation, etc., and such other investigations as appeared necessary for the solution of the several problems involved.

William Ham Hall was appointed State Engineer to direct the work for which the department was created. His corps of assistants included such men as C. E. Grunsky, Marsden Manson, James Dix Schuyler, and others, whose later professional attainments have given them illustrious positions in the world's engineering field.

A vast amount of data along all the lines demanded was collected and portions of it were published, but before it could be digested and presented in form to be of value, political bickerings and a parsimonious spirit cut off the appropriations, and finally repealed the law creating the State Engineering Department. Thus was lost the fruits of years of toil in accumulating information needed in the formulation of laws and execution of works to correct grievous conditions that had so long been suffering for relief. To discontinue the State Engineering Department and its labors, at the time when—to use a homely figure of speech—it was just "getting on its feet," was a blunder little short of a crime.

Research along the lines inaugurated by that engineering department before its demise has been pursued spasmodically by different boards, commissions or individuals, but there is in every line an interruption of continuity of the record which more or less discredits deductions drawn from such incomplete data. To cite an instance: A hiatus exists in the record of stream gagings from the suspension of work by the State Engineer in 1884 until observations were commenced by the United States Geological Survey in 1894. In 1904 a board of eminent engineers, the members of which had been engaged for many years in successfully carrying out similar enterprises, offered an elaborate plan for the control of floods on the Sacramento. The magnitude of the works was designed in accordance with the best information obtainable as to the quantity of storm water to be provided for. But the records of flood flow secured since 1904 by cooperative effort between the Geological Survey and the state have caused the engineers submitting the latest scheme (which the legislature has approved) to provide channel-way for two and three tenths as much water. That is to say, later research indicates that more than 600,000 cubic feet of water a second must be cared for as against 260,000 second-feet, believed to be the maximum according to the data available in 1904.

With the continually increasing number of industries depending upon technical direction, advice, or assistance—which no other agencies could so well provide as the government—came additional commissions or boards to conduct research and direct administration. To consolidate several of these agencies into one with a single executive head the legislature in 1907 provided for the organization of the State Department of Engineering.

The act creating this department (Chapter 183, Statutes 1907, approved March 11, 1907) abolished the offices of Commissioner of Public Works, Auditing Board to the Commissioner of Public Works, Department of Highways and State Highway Commissioner, Lake Tahoe Wagon Road Commissioner, and Debris Commissioner, and dele-

gated the performance of their several duties to the Department of Engineering. To the department was also assigned all engineering work for the Board of Harbor Commissioners of San Francisco and the design and construction of buildings and works for all the hospitals, prisons, and schools, and other state institutions. It was given authority to cooperate with the Department of the Interior and other departments and bureaus of the national government in making surveys, investigations, etc.

Mr. Nathaniel Ellery was appointed to the position of state engineer and chief executive officer of the Department of Engineering, and assumed the office May 11, 1907. He was succeeded in office by the appointment of Mr. Wilbur F. McClure, February 13, 1912.

The records of the organization of the department and the work accomplished by it from the date of its establishment to November 30, 1912, have been published in the biennial reports issued in 1908, 1910, and 1912, respectively, and it is the office of this report to review the operations of the department during the biennial period just closing.

Since the department was created, each session of the legislature has enacted laws amending the statutes affecting the work of the department, the most notable of which was to enable it to handle the administration of the State Highways Act of 1910, which appropriated $18,000,000 for a system of state highways. Many of the statutes enacted have added greatly to the functions of the department.

DEPARTMENT OF ENGINEERING.

Under the statutes now in force the Department of Engineering is composed of three bodies: Advisory Board, Consulting Board, and Executive Force. These three bodies are constituted respectively as follows:

THE ADVISORY BOARD.

Governor, ex officio member and chairman.
General Superintendent of State Hospitals, ex officio member.
Chairman of Board of State Harbor Commissioners of San Francisco, ex officio member.
State Engineer, appointed by the Governor, ex officio member.
Three members, appointed by the Governor.

The Advisory Board is the administrative head, and directs the operations of the department through the State Engineer, who is the chief executive officer of the department.

The ex officio members receive no salary as members of the Advisory Board. The three last named appointed members of the Advisory Board are delegated as a special executive committee of the board to administer the affairs of the $18,000,000 state highway bond project, and

bear the title of State Highway Commission. These members are paid salaries.

THE CONSULTING BOARD.

This board is composed of five members appointed by the Governor and serve without compensation. The functions of this board are to act as intermediary between the people desiring public work done on the rivers and the Department of Engineering; receive and consider petitions and make recommendations to the department in regard to proposed work pertaining to drainage, irrigation, and river improvement. This board holds meetings at the call of the State Engineer.

EXECUTIVE FORCE.

State Engineer, Chief Executive Officer.
Two Assistant State Engineers.
State Highway Engineer.
State Architect.
Mechanical Engineer.
Testing Engineer.
Architectural Designer.
Three Architectural Draftsmen.
Two Engineer Draftsmen.
Secretary.
Two Clerks and Stenographers.
Two Filing Clerks.
Blue Print Pressman.
Porter and Messenger.

One of the assistant engineers and one engineer draftsman are assigned to duty with the State Board of Harbor Commissioners at San Francisco.

The foregoing comprises all of the "statutory" employees of the department.

The field of operations conducted by the Department of Engineering has been continuously expanding, so that it has become necessary to arrange its executive force into sections, for better administration. The expansion of the department's field of operations has been so rapid that it was found necessary to create additional offices to execute the work demanded.

The universal employment of electricity for lighting, power, communication, and in the hospitals its extensive use in therapy, requires a large force of electricians, and to properly direct their work, the employment of an electrical engineer is necessary.

A vast amount of construction and repair of state property is done directly by the Department of Engineering, entailing the purchase of immense quantities of materials, machinery and apparatus.

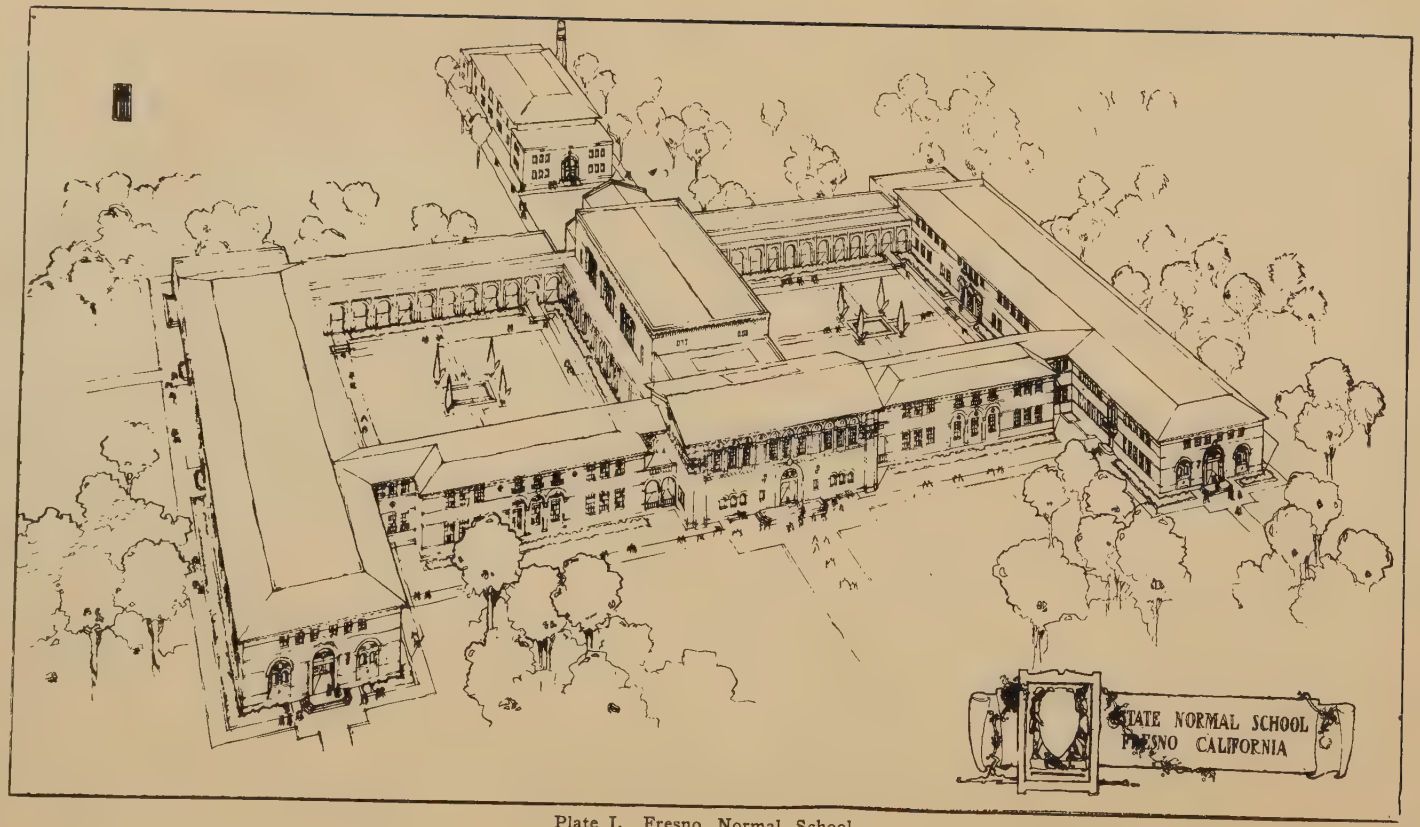


Plate I. Fresno Normal School.

Plate II. Training School, Chico Normal School.

Plate III. Training School, Open-air Class, Chico Normal School.

The orders sent out have averaged about sixty a day, and each order is based upon quotations of price from never less than three competitive dealers. To effect economy in this line a purchasing office is maintained under the direction of a purchasing agent.

The expenditure of several millions of dollars entrusted to the department requires a considerable force of accountants, directed by an auditor.

In addition to those enumerated above, the department has required the services of draftsmen, architectural and structural engineers, surveyors and their crews, superintendents, inspectors, and men in many other capacities, down to cooks, waiters, and roustabouts in the road and river construction camps.

The foregoing list of employments indicates to some extent the varied nature of the department's activities and the extent of the field covered by it. Its duties, as specified by several statutes, are summarized as follows:

To make plans and specifications for all buildings at the various state institutions, to let contracts for and superintend their erection, or, in case satisfactory contracts can not be made, to construct the buildings by day labor. To design and install all heating, lighting, ventilating, refrigerating, water supply, sewerage, and mechanical plants of every nature—whether changes, extensions or original. Survey grounds, lay out walks, drives and roads; provide water supply, irrigation, reclamation, sewer and drainage systems, requiring the design and construction of dams, reservoirs, pipe lines, wells, pumping plants, ditches, sewage treatment and disposal plants and drains.

Design and construct works for the protection of river levees, preservation of navigation and protection from floods.

Conduct research looking to the reclamation of the overflow basins and to effect flood control on the Sacramento and San Joaquin rivers.

Studies of the feasibility of navigable canals and canalization of rivers.

Through the engineering force assigned to the Board of Harbor Commissioners, to design and direct the construction of wharves, piers, buildings and their equipment on the water front of San Francisco.

Location, construction, repair and maintenance of state roads, of which there are nearly 600 miles in the mountain regions.

Through the Highway Commission, the location and construction is being conducted of the system of highways authorized by the eighteen million dollar bond act.

The administration of the Motor Vehicle Act, involving the issue and registry of all licenses for motor vehicles. The issuance of licenses for

the operation of motor vehicles was placed in the Department of Engineering by an act approved May 31, 1913. To handle the matters pertaining to this required the erection of a division especially for that purpose.

By cooperation with the federal government a topographic survey of the state is being made; daily measurements are made of the water flowing in all the principal and many of the minor streams of the state; studies of possibilities for developments of power in the mountains and irrigation in the plains; investigation of the use and abuse of water in irrigation; the quality of waters, etc.

This department is required to cooperate with the engineers of the war department in matters concerning débris control, flood control, and aid to navigation.

The State Engineer is required to investigate and pass upon the feasibility of the enterprise before an irrigation district can be organized. He is a member of the Irrigation District Bond Commission and is required, upon application, to investigate the engineering features of the projects of existing irrigation districts, where the latter desire to have their bonds accepted as state securities, and supervises the construction of works executed with proceeds of validated bonds.

He is ex officio a member of the State Water Commission, created by an act to be approved by the people at the coming election, which body will have control of all water appropriations and the adjudication of water rights.

The State Engineer is required by law to direct the engineering investigations for the Reclamation Board to determine the proper location and sufficiency of proposed reclamation works, so that they shall conform to the plan for the flood control adopted by the state.

Plans for all bridges to cross navigable streams are required to be approved by the State Engineer before they are permitted to be erected.

In addition to the active duties enumerated above, the department conducts an extensive correspondence, answering queries from all over the country seeking information in regard to the extent of drainage, reclamation, irrigation and power developments, and many other lines of progress in the state, and the costs thereof. If the information is at hand or can be obtained it is always furnished. This is done upon the theory that all public offices should be in a measure publicity bureaus, and the dissemination of correct information as to the resources of the state and its advantages is a proper function of all branches of the government.

The department has been called upon by municipalities for advice in regard to sewage disposal; by communities asking for the examination of dams, as to their stability and safety, and specifications to strengthen the same, as well as advice regarding flood protection and stream control in different portions of the state. While these are not duties

enjoined by law upon the department, the State Engineer has always responded to such requests and given such assistance in an advisory way as the department was able to furnish, and it is gratifying to know that such aid has been regarded of value by the recipients.

PERSONNEL.

At the date of this writing, November 30, 1914, the Department of Engineering is organized as follows:

ADVISORY BOARD.

Hiram W. Johnson—Governor (Chairman)
W. F. McClure—State Engineer
J. J. Dwyer—President State Board of Harbor Commissioners
F. W. Hatch—General Superintendent of State Hospitals
Charles D. Blaney (Chairman), N. D. Darlington, Charles F. Stern (succeeded B. A. Towne, resigned)—State Highway Commission

CONSULTING BOARD.

Alexander Gordon—President
G. W. Tatterson, Stockton
W. J. Smith, Grand Island
M. J. Boggs, Colusa
E. S. Brown, Sacramento

EXECUTIVE FORCE.

Title	Name	Date assumed office
Executive Office.		
State Engineer	Wilbur F. McClure	Feb. 12, 1912
Assistant State Engineer	Paul M. Norboe	May 17, 1907
Secretary	Earle Freeman	Mar. 13, 1912
Stenographer and Clerk	Lucy K. Adams	April 1, 1912
Stenographer and Clerk	Henrietta Burt	May 16, 1913
Porter and Messenger	George J. Scully	Dec. 1, 1912
General Engineering.		
Civil Engineer	E. D. Nickerson	April 18, 1912
Engineer Flood Control	E. A. Bailey	June 1, 1912
Engineering Draftsman	Edward Goodwin	May 27, 1907
Superintendent of River Work	W. W. Wooldridge	Jan. 1, 1908
Harbor Commission.		
Assistant State Engineer	Jerome Newman	Aug. 8, 1912
Engineering Draftsman	A. W. Nordwell	Feb. 1, 1913
Highway Commission.		
Highway Engineer	A. B. Fletcher.	

ACCOUNTING DIVISION.

Title	Name	Date assumed office
Auditing Section.		
Auditor	J. H. Clarke	Nov. 11, 1911
Filing Clerk	Charles Johnston	April 1, 1909
Filing Clerk	J. C. McCalmont	Mar. 26, 1912
Clerk	A. J. Adams	April 15, 1912
Clerk	N. E. White	April 15, 1912
Purchasing Section.		
Purchasing Agent	H. A. French	Feb. 13, 1912
Clerk	C. O. Palm	July 11, 1911
Stenographer	Anna Gates	June 1, 1914
Stenographer	Sadie I. McGorvin	April 1, 1914
Messenger	Leland Ayer	Mar. 23, 1914

ARCHITECTURAL DIVISION.

Title	Name	Date assumed office
State Architect	George B. McDougall	Aug. 22, 1913
Architectural Designer	Charles F. Dean	Sept. 23, 1911
Chief Draftsman	James S. Dean	Aug. 1, 1912
Stenographer	Grace E. DuFour	Aug. 1, 1913
Stenographer	Elsa Koch	Mar. 25, 1914
Messenger	Harold McMillan	Oct. 1, 1914
Designing Section.		
Architectural Draftsman	R. E. Backus	Sept. 1, 1912
Architectural Draftsman	O. R. Baxter	Aug. 2, 1909
Architectural Draftsman	W. A. Baumberger	Aug. 24, 1914
Architectural Draftsman	P. W. DeLongchamps	Aug. 11, 1913
Architectural Draftsman	J. G. Heath	Feb. 1, 1913
Architectural Draftsman	W. E. Hough	Aug. 11, 1913
Architectural Draftsman	Walter J. Long	Nov. 20, 1912
Architectural Draftsman	W. J. Mellin	Aug. 3, 1914
Architectural Draftsman	H. E. Mackie	May 11, 1914
Architectural Draftsman	C. P. Pierson	Jan. 20, 1913
Architectural Draftsman	Frederick Ruckh	Mar. 17, 1914
Architectural Draftsman	W. A. Stone	Aug. 3, 1914
Architectural Draftsman	Leroy F. Sherwood	Jan. 1, 1913
Architectural Draftsman	Henry E. Sterry	Jan. 1, 1913
Architectural Draftsman	V. S. Stimson	Aug. 25, 1913
Architectural Draftsman	A. R. Widdowson	July 17, 1911
Architectural Draftsman	W. J. Young	May 18, 1907
Blue Printer	Frank J. Butler	April 1, 1912
Structural Section.		
Structural Engineer	Clarence H. Kromer	Feb. 16, 1913
Structural Draftsman	H. E. Lowe	Aug. 10, 1914
Structural Draftsman	V. B. Stanbury	Nov. 9, 1914
Mechanical Section.		
Mechanical Engineer	L. B. Luppen	Aug. 1, 1912
Assistant Mechanical Engineer	H. H. Blee	April 10, 1913
Mechanical Draftsman	C. A. Henderlong	April 28, 1914
Mechanical Draftsman	P. H. Steiner	Oct. 19, 1914
Mechanical Draftsman	A. J. Zschokke	Jan. 7, 1914
Mechanical Draftsman	J. Zipf	April 27, 1914
Electrical Section.		
Electrical Engineer	G. D. Jones	Oct. 1, 1912
Electrical Draftsman	G. M. Simonson	Sept. 22, 1913
Testing Section.		
Testing Engineer	E. D. Griffith	Mar. 22, 1909
Assistant Testing Engineer	H. M. Clifford	Aug. 3, 1914

MOTOR VEHICLE DIVISION.

Title	Name	Date assumed office
Superintendent	W. R. Ormsby	Aug. 20, 1913
Assistant Superintendent	W. S. Goble	Oct. 15, 1914
Chief Clerk	A. J. Healey	Sept. 1, 1913
Assistant Clerk	Lolita Jodon	Oct. 9, 1914
Filing Clerk	E. F. Peterson	Feb. 28, 1914
Registry Clerk	G. E. Baugh	June 1, 1914
Shipping Clerk	W. R. Bowen	Sept. 15, 1914
Assistant Shipping Clerk	M. L. Stone	Nov. 9, 1914
Transfer Clerk	M. P. Stone	June 8, 1914
Clerk	S. L. Blodgeth	Sept. 21, 1914
Stenographer	A. G. Bird	Sept. 1, 1913
Stenographer	Edith Krause	Mar. 1, 1914
Stenographer	Irma Russell	July 15, 1914
Stenographer	Mrs. Laura N. Shaw	July 15, 1914
Stenographer	Nell Stephens	Mar. 1, 1914
Messenger	John Frankhauser	Dec. 26, 1913
Messenger	George J. Scully, Jr.	Jan. 1, 1914

In addition to the above, which constitutes a permanent force required for the orderly conduct of the various duties devolving upon the Department of Engineering, there is a large number of semi-permanent and temporary employments such as road engineers, foremen and laborers, teamsters, cooks, etc., employed on mountain roads during the summer; foremen, laborers, cooks, etc., employed from time to time on river work; draughtsmen, tracers, computers, inspectors, etc., required in the architectural division during rushes of work, and extra clerks and stenographers in the motor vehicle division near the end of each year to prepare and ship new license plates to automobile owners.

STATE INSTITUTIONS.

The state institutions for which the services of the department of engineering are required under the law, are as follows:

Educational.

Chico State Normal School.
Fresno State Normal School.
Humboldt State Normal School, Arcata.
Los Angeles State Normal School.
San Diego State Normal School.
San Francisco State Normal School.
San Jose State Normal School.
Santa Barbara State Normal School of Manual Arts and Home Economics.
San Luis Obispo State Polytechnic School.

Eleemosynary.

California Institution for the Deaf and the Blind, Berkeley.
Industrial Home of Mechanical Trades for Adult Blind, Oakland.

State hospitals.

Agnews, Agnew, Santa Clara County.
Mendocino, Ukiah, Mendocino County.
Napa, Napa, Napa County.
Norwalk, Norwalk, Los Angeles County.
Southern California, Patton, San Bernardino County.
Stockton, Stockton, San Joaquin County.
Sonoma State Home (for feeble-minded children), Eldridge, Sonoma County.

Punitive.

State Prison, Folsom, Sacramento County.
State Prison, San Quentin, Marin County.

Reformatory.

Preston School of Industry, Ione, Amador County.
Whittier State School, Whittier, Los Angeles County.
California State Reformatory, Yountville, Napa County (not yet established).
California State School for Girls, Ventura, Ventura County.

Military.

Veterans' Home, Yountville, Napa County.
State Arsenal and Armory, Sacramento.
State Armory, San Francisco.
State Armory, Los Angeles.

Miscellaneous.

State Capitol, building and grounds, Sacramento.
Governor's Mansion, Sacramento.
State Printing Office, Sacramento.
State Fair, buildings and grounds, Sacramento.
Sutter's Fort, buildings and grounds, Sacramento.
Harbor Front, wharfs, piers and buildings, San Francisco.
Mission Solano, Sonoma County (restoration).
Los Angeles Exposition Building, Los Angeles.
State Office Buildings, Sacramento (authorized, not commenced).
State Office Buildings, San Francisco (authorized, not commenced).

Architectural service at state institutions.

All work of the department pertaining to state buildings, whether relating to the preparation of plans and specifications, or erection and installation, including mechanical plants of every kind, is executed by the architectural division of the department, and a review of the work, accomplished by that division will be found under the appropriate caption.

Engineering service at state institutions.

Whenever improvements are contemplated at an institution, whether it be a new building, or whether water pipes, sewers, walks or drives are to be extended, the first thing needed is a topographic map, showing the location of existing buildings and all the natural and artificial topographic features of the grounds. To meet this demand the department has from time to time executed surveys at several institutions and constructed maps thereof, so that now the department possesses such maps of nearly all state institutions.

The engineering service executed since its last biennial report, other than that performed under the direction of the architectural division, has been as follows:

Veterans' Home.

Water supply.—This ever present question at public institutions reached an acute stage at this home. The ordinary domestic supply is obtained from wells and is pumped into tanks situated on a hillside above the buildings. This is supplemented for irrigation by a supply

from a reservoir three fourths of a mile up a rocky ravine. The dam forming this reservoir is a "rock fill" dam sixty feet high. It was built several years ago, to a height of fifty feet, but failed to hold the water. Several attempts were made to render it water tight, but without success. When the Department of Engineering came into existence in 1907, the dam was remodeled. The old lumber skins (of which there had been three, put on one above another) were removed and a concrete facing put on, well trenched into the bedrock. The dam was also raised ten feet in height, and when the water came the reservoir filled to the top, whereas sixteen feet had been the greatest depth held before. The reservior is fed by the canyon in which it is situated but, having a very limited watershed, the stream ceases to run almost by the time irrigation begins, so that one filling is all that can be obtained, although the stream is estimated to flow an amount about twice the capacity of the reservoir, which is 22,000,000 gallons.

A representative of this department made an examination of every canyon and ravine or flat of the estate. Several places had been recommended as suitable reservoir sites, but none were found which appeared to the professional mind as being well adapted for the purpose. There are several locations where storage may be found; one a short distance above the present reservoir and one or two below, but none possessing capacity commensurate with the probable cost.

The dry summer of 1912 curtailed the supply of water to a point that entailed actual discomfort. The reservoir was entirely exhausted; the wells ceased to furnish their wonted flow, and despite the practice of the utmost economy in the use of water, lawns, trees, and shrubbery showed plainly the effects of drought. Water for baths, laundry, and flushing was restricted to the lowest possible limit, and yet it seemed that suffering must ensue unless relief was quickly found. The commandant and the engineer of the power plant had discovered that several wells in the valley just off the lands of the Home were reported to be capable of furnishing large quantities of water and suggested that a well in the same vicinity might yield a supply.

There being no appropriation available it was imperative that whatever relief could be found must be such as could be provided at a cost within such limited amount as could be spared from the contingent and maintenance funds of the institution.

Upon request, this Department investigated the matter and recommended the excavation of a large pit at the border of the property of the Home, in a position where the configuration of the ground indicated that the same underground stream should be encountered which furnished the wells of known good flow.

An elliptical pit 20 by 30 feet in dimensions and about 30 feet deep was dug and curbed with a rock wall all around. A pump and motor were installed and a pipe line laid connecting into the piping system at the buildings, which enabled a fair supply of excellent water to be obtained.

This expedient, while relieving the drought conditions, is an expensive one to operate, requiring the pumping of the water through pipes more than half a mile and against a head of about 170 feet, all of which is expensive.

The state had acquired a large tract of land known as the Frye Ranch, some four miles away. Upon this property is a perennial stream affording more water than the land will be able to utilize for a long time. An appropriation was made to lay a pipe line to convey a portion of the water to the Veterans' Home. The amount of the appropriation, $12,000, was determined without consulting the Department of Engineering, and without sufficient data as to the requirements. It had been supposed that a 4-inch pipe about four miles long would be required, which could have been installed for the funds appropriated, but when the surveys were made by the Department it was found that six miles of pipe would be required to reach a point sufficiently high to force the required quantity of water through a 6-inch iron pipe.

It was found, however, that a wood-stave pipe, five inches in diameter would deliver the required quantity and could be installed for a sum within the appropriation. That type was adopted and the Home now has a daily supply of more than 100,000 gallons in addition to its former supply from wells and storage.

Sewer system.—Formerly the sewage of the Home was discharged into a ravine which traverses the lowlands and discharges into Napa River. This practice resulted in creating a nuisance which the health authorities ordered to be abated.

Appropriations have been made from time to time, which have enabled the Department to gradually improve conditions by first constructing hydrolytic tanks for the liquefaction of the sewage, followed by the addition of treatment apparatus, and finally the relaying, during 1914, of a complete system of sewer pipes to take the place of the old system, which was extremely faulty in design and construction.

The present plant is operated satisfactorily.

Stockton State Hospital.

Flood protection.—The hospital possesses a farm about two and one half miles north of Stockton, which lies along the Calaveras River. The land is protected from the waters of this river and from the back water of the San Joaquin River by levees enclosing it on three sides.

But the banks of the Calaveras River several miles upstream are not provided with adequate levees, and a recently constructed canal, made by the Federal Government to divert the water of Mormon Slough into the Calaveras River, brings so much water from the slough that the river is engorged and overflows its banks. The escaping water follows depressions in the plains over and across intervening lands, and in a flood during the spring of 1909 it accumulated on the farm of the state hospital against the levees, and destroyed the trees of quite a large fruit orchard. The accumulated waters here broke the levee and flowed thence into the San Joaquin River.

An effort was made to enlist the cooperation of adjoining land owners in adopting protective measures, but without success. A means of obtaining relief was later found, which is described in a following chapter discussing river work.

Agnews State Hospital.

Water supply.—The supply of water for domestic use and irrigation is obtained from artesian wells. The principal well, and the one which furnished the domestic supply is near the power plant. The water is pumped into tanks 84 feet above the ground. The summer of 1912 was noted as being one of the driest seasons recorded. The flow from all the wells declined to such an extent that the reserve for fire purposes was seriously threatened. A representative from the Department suggested some temporary expedients for conserving the supply available, which were successful in carrying the institution over the dry season.

The following season, the water supply being inadequate for all purposes, an air-lift was installed in the well at the power house, which increased the supply from this well sufficiently to meet all demands.

Drainage.—The outfall sewer at this institution is a 12-inch pipe discharging into a slough four or five miles away, and thence into San Francisco Bay. The pipe is too small to carry more than the sewage, and when the roof drains of the buildings were connected into it the pipe was taxed beyond its capacity. In 1912 a system of surface drains was devised and installed which has taken care of the water from roofs and walks in a satisfactory manner.

Soil Drainage.—A large portion of the estate of this hospital is low and swampy in character, producing but a meager quantity of inferior stock feed. The soil would be quite productive if it were thoroughly drained. Some years ago drain tiles were laid in a portion of it, but they were not judiciously placed and have not proven successful. In 1912 a plan was formulated, but lack of funds prevented its being installed. The reclamation of so much land which is so nearly valueless in its present state should be given earnest consideration.

Plate IV—A. Conservatory, Capitol Park, Sacramento.

B. Nursery for Boys, Sonoma State Home.

C. Ward 25, Stockton State Hospital.

Plate V—A. Recreation Hall, Napa State Hospital.

B. Farm Cottage for Males, Mendocino State Hospital.

C. Laundry, Southern California State Hospital.

Mendocino State Hospital.

Dam and Reservoir.—The legislature of 1911 appropriated the sum of $12,500 for the construction of a dam to create a reservoir in a canyon about two and one half miles from the hospital upon land which the institution had secured some years ago for the purpose of protecting the watershed supplying two other reservoirs on the same creek. For a description of the dam the report of 1912 is here quoted.

Excavation for the foundation began in the summer of 1911, and most of the site was stripped down to bedrock. In excavating for foundation, it was found that rock which had been supposed was bedrock, proved to be a broken mass which had been deposited by a slide from the mountain side. Extensive explorations were necessary to determine the extent of it, which proved so great that much of the appropriation was expended in reaching material which was acceptable for a foundation. Such was found, however, but at a depth in places, of more than forty feet from the ground surface.

The dam designed is a concrete, gravity section, overflow type. An abundance of hard trap rock is found within a hundred feet of one end of the dam, which is broken out and run in a chute down to the rock crusher. The maximum height from base to crest will be 63 feet, length on crest 350 feet, width of base 38 feet, crest 4 feet.

The outlet is an opening 36 inches wide by 42 inches high, controlled by an iron sluice gate operated from the top of the dam by a screw stem and gearing.

Waste, in excess of the capacity of the outlet to care for, will pour over the crest in a broad sheet only a few inches deep, so no special provision is made for that. A 24-inch pipe is laid through the dam at the level of the outlet to provide means of conveying water under pressure to the hospital, should this be found desirable. This can be easily done by extending a pipe which now takes water from another reservoir about four thousand feet below this dam. This pipe will be closed until a connection shall be made.

The storage capacity of the reservoir is estimated at 45,000,000 gallons. This, in connection with 8,000,000 gallons held by the reservoir below, should provide ample supply for any extension of the institution likely to occur in many years.

The legislature in 1913 appropriated an additional sum of $12,500, and the work of construction has gone steadily on whenever weather conditions would permit.

The concrete work is up to the 50-foot level. Outlet works are in place.

The work has been done almost wholly by the labor of patients under the direction of F. C. Handy, steward of the hospital, who has represented the Department in all of this work.

Sewerage.—The method of sewage disposal at this institution is broad irrigation after the sewage has been liquefied by passing through a hydrolytic tank. At the farm, situated something more than a mile from the hospital, new cottages have been recently erected which necessitated the installation of a separate sewer system, including a small hydrolytic tank. This was completed last year under Mr. Handy's direction.

Napa State Hospital.

Tide Land Reclamation.—This hospital owns a tract of land lying along the bank of the Napa River, embracing about 380 acres, which is subject to overflow from high tides and from flood water of Tulucay Creek, which traverses it. Two years ago the Department formulated a plan for its reclamation. The legislature of 1913 appropriated $10,000 for the purpose, with which sum the project has been completed. This adds more than 380 acres of tillable land to the domain of the hospital. The plan as carried out consisted of changing the channel of Tulucay Creek so as to run across the north end of field and empty into Napa River near the station Imola on the Southern Pacific Railroad; constructing a levee along the south bank of the new channel and extending along the left bank of the river to the original mouth of the creek, thence up the right bank of that channel nearly to the railroad bridge across it, where a dam was placed in the creek and extending to high land on the east side.

This places a levee or dike entirely around the low side of the land, thus shutting out the flood water of Tulucay Creek and the tidal flow of Napa River.

To effect the change in the channel of the creek it was necessary for the hospital to purchase a small tract of about two acres at the mouth of the new channel, and for the railroad to build a trestle across the channel and raise its track about three and one half feet. The cost of the entire work was $10,621.61, including several hundred dollars paid for a right of way that had been verbally promised to be given free and was not included in the original estimate.

Southern California State Hospital.

Railroad Spur.—It became desirable to have a spur track extended from the main line of the Atchison, Topeka and Santa Fe Railroad Company to the new power house of the institution for the ready delivery of fuel and other commodities.

The railway company and the hospital management failing to arrive at an agreement in the matter, it was referred to the Railroad Commission and Board of Control. An engineer from the Department of Engineering representing the Board and an engineer from the Commission met the representatives of the railway company and agreed upon all disputed points, settling the controversy.

Norwalk State Hospital.

Topographic Survey.—A survey and contour map of the estate of this institution has been made which has proved useful in selecting building sites.

Sewerage.—A general plan for sewage disposal has been worked out and the drawings partially prepared.

Plate VI. Southern California State Hospital (General view).

Plate VII. Cottages, J, K, L and M, Southern California State Hospital.

Ventura State School for Girls.

This institution, provided for by an act of the legislature of 1913, was located two miles from the city of Ventura, Ventura County.

Topographic Survey.—A survey has been made of part of the grounds sufficient to enable the location of buildings to be made.

Roads.—A road from the main highway to the building site is being constructed.

Sonoma State Home.

Water Supply.—The water for domestic use at this institution is obtained from several springs in the wooded ravines of the hills in the western portion of the estate. The water, which is of most excellent quality, is conveyed in iron pipes to two concrete tanks of about 1,000,000 gallons capacity, each situated on a hill about 150 feet in elevation above the grounds of the Home. From these tanks it is distributed to the buildings and grounds. For many years this source furnished sufficient water for domestic purposes and also for irrigating the lawns, but with an increase in population the supply became inadequate.

In 1910 the Department constructed an earthen dam across the lower end of a small valley in the hills about a mile back of the home, creating a reservoir with a capacity of about seventy-five acre feet. The material available for its construction at the site of the dam is a residual soil formed by disintegration in place of the volcanic rock abounding in this region. The soil is of a clayey nature and extremely incoherent when wet. Recognizing its unstable character, a "puddle core" was introduced consisting of sand and gravel hauled from the bed of Sonoma Creek, two miles away and 370 feet lower elevation. The sand and gravel being mixed with a proper proportion of the local soil, made a very impervious corewall.

In 1911 the height of the dam was raised five feet, its design contemplating that and providing for another five-foot raise if required.

The watershed directly tributary to the reservoir does not ordinarily furnish sufficient runoff to fill it, but ditches have been constructed from two creeks draining adjoining watersheds which will enable the reservoir to be readily filled to its capacity.

A separate pipe system was installed connecting the reservoir to the sprinkling system at the grounds without letting any of this surface water into the domestic supply.

The season of 1912 was unusually dry and, notwithstanding the supply from the reservoir, much inconvenience was felt. A temporary installation of a pump and well in the creek bottom delivering water into the irrigating pipes carried the institution through that season.

The vegetable gardens are situated on the opposite side of Sonoma Creek Valley from the home, and more than a mile away, with a low ridge between.

Irrigation is required for the production of most vegetables grown here, and water for this purpose is obtained from some small springs. During the series of dry years since 1909 these springs have gradually decreased their flow until it became necessary to obtain water from some other source.

A pump operated by a gasoline engine was installed in Sonoma Creek, and a 4-inch pipe laid over the ridge mentioned to a point above the gardens whence the water is distributed.

With all of these expedients the consumption, particularly for domestic use, is so nearly the limit of the supply that it causes much concern, especially in view of the certain need for enlarging the institution.

The legislature in 1913 appropriated $10,000 for additional water supply, and this is being expended in boring a well in the valley. The well has reached a depth of 350 feet, intercepting two or three small flows of water, but not sufficient for its purpose. Provision is made in the contract to bore to a depth of 700 feet if it be found necessary. It is not possible to predict from the formations exposed that an abundant supply will be reached, but the attempt will be continued with hopes for success.

Sewerage.—The sewer system here was constructed many years ago when the population was small and housed in but few buildings. The location of the pipes was not well chosen to meet the demands created by the rapid growth of the institution.

The method of disposal of the sewage was designed by one not versed in sanitary science. It is wrong in principle and has always given trouble.

The last legislature appropriated $5,500 for the purpose of remodeling the system. A hydrolitic tank is being constructed with provision for chemical treatment of the effluent, and new lines of pipe laid to take the place of badly located lines, the entire scheme of which is arranged for enlargement to meet the requirements of future expansion of the home.

Roads and Drives.—The estate of the home comprises about 1,700 acres, nearly all of which is rolling or hilly, the highest portions being nearly a thousand feet above the grounds about the main buildings.

The hay fields as well as some of the best orchard lands are in the uplands, so that much hauling is required from here. The roads are very steep in many places. The soil is easily eroded and when wet

Plate VIII. Cloistered Shelter, Exercise Yard, Male Wards, Mendocino State Hospital.

is given to sliding in masses. Its unstable character, coupled with the steep gradients, make the roads difficult to maintain, and hard to haul over in wet weather.

A group of cottages has been built on a hill overlooking the main buildings and about eighty feet above them. A new road was laid out to them and constructed during the past summer. A method of surfacing was introduced which it is hoped will improve the roadway. Sand and gravel were hauled from the creek bed and thoroughly mixed with the local clay soil, laid on proper grade with gutters to carry away the rainwater. Constructed in this manner, it is hoped a good roadbed will result.

State Fair Grounds.

An act approved June 6, 1913, appropriated $10,000 to be used for the disposal of drainage and sewage from the State Fair Grounds at Agricultural Park, Sacramento.

Owing to the absence of any sewers or means of public disposal of sewage in the portion of the city where the fair grounds are situated, sanitary conditions were extremely bad, and growing worse at each recurrence of the State Fair.

In preparation for the fair to be held in September, 1913, there being no sewer in the vicinity of the fair grounds, a temporary system was installed consisting of hydrolitic tanks and cesspools, with an overdischarge into a drain that led out of the grounds.

The unprecedentedly large attendance at the fair taxed the system beyond its capacity, and the discharge through the drain mentioned created a great nuisance in nearby neighborhoods.

To avoid a repetition of these conditions in 1914, prior to the beginning of the State Fair, a pipe line of 4-inch screwed pipe was laid from the hydrolitic tank to connect into a force line from the county hospital, 2,000 feet away, which line in turn connected into the city sewers more than half a mile distant. An electrically driven centrifugal pump was installed to force the sewage through the pipe, and all sewers were disconnected from the drain and connected into the tanks. The expedients sufficed, but the plant was taxed to its utmost.

It is hoped that before another season shall arrive the city's systems will have reached the neighborhood of the grounds, so that all sewage may be discharged directly into them.

THE ARCHITECTURAL DIVISION—REPORT OF OPERATIONS

From November 1, 1912, to October 31, 1914.

By GEORGE B. MCDOUGALL, State Architect.

The Architectural Division of the Department of Engineering does all architectural work, structural engineering and mechanical engineering, which latter includes power plant, heating, ventilating and electrical engineering, as required in connection with all new construction and all repair work at thirty-two different state institutions, which have a combined population in students, patients and prisoners of about twenty thousand.

There were authorized in 1913 eighty-five appropriations aggregating $3,058,405 for building construction at these various institutions, and, in addition to this, estimates from the several boards of management have been approved during the past two years for fifty-one different pieces of construction, aggregating in cost $163,973.81; this added to the amount of the appropriations makes a total of $3,222,378.81 for one hundred and thirty-six different pieces of work.

There is necessarily a considerable amount of office work done in connection with proposed construction at these various institutions that is never carried through and is not taken into account in the above figures. In addition to this, it is impossible for us to deny requests for counsel and advice from the various institutions, and the aggregate amount of time given during a biennial period to consultations, making of sketches and general assistance is very considerable.

Of these one hundred and thirty-six pieces of work referred to above, twenty-seven were of a value less than $1,000; seventy-two between $1,000 and $12,500; sixteen between $12,500 and $20,000; twelve between $20,000 and $50,000, and nine over $50,000.

The extremely large proportion of work of small cost, as indicated by the figures just given, together with work in connection with proposed construction never erected and the large amount of time consumed in advisory consultation, already referred to, make the average percentage of cost for our office work higher than would be the case otherwise.

Plate IX. Ice Plant (front), San Quentin State Prison.

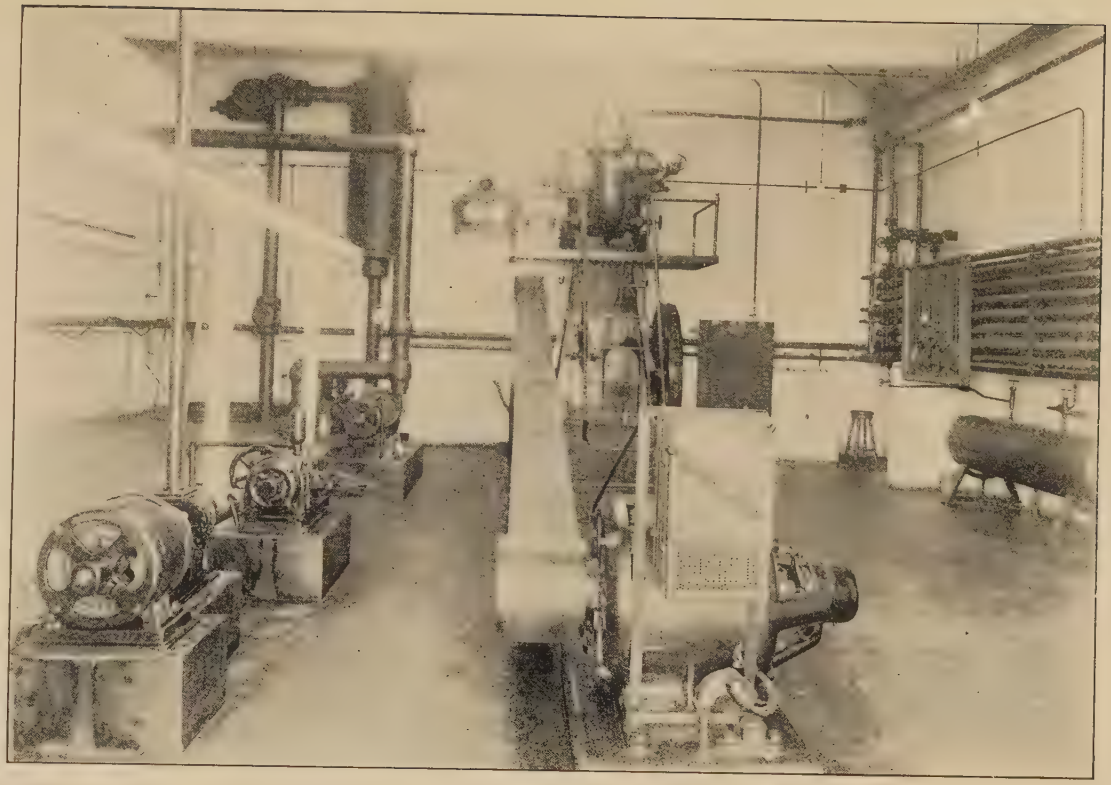


Plate X. Ice Plant, San Quentin State Prison.

For the purpose of indicating in detail the cost of our work, a list of forty items fairly representing the total of one hundred and thirty-six, is given at the end of this report. The total cost of these forty pieces of construction as shown by our books is $1,238,471, the expense of our office work $51,378.40 or 4.14 per cent of the total, and the expense for inspection $7,749.13 or 0.51 per cent of the total. Since some work still remains to be done in connection with a few items on the list referred to, the above percentages should be respectively 4.50 and 0.75 per cent.

Some conditions that have tended to keep maintenance cost up have been and are still being gradually removed. The office is now a better organization and is operated under a better system than at any time heretofore. The several branches of work are coordinated and a high degree of efficiency is obtained. Our quarters in the Capitol have been insufficient and quite unsatisfactory in other important particulars; this is to be remedied by our removal about January 1, 1915, to ample and satisfactory quarters in the Forum building.

The schedule of proper minimum charges of the American Institute of Architects, which schedule today governs the practice of all our best architects, makes 6 per cent of the total cost the architect's minimum compensation in any case, and where the work is of small cost, and in connection with the remodeling of existing buildings, 10 per cent and sometimes 15 per cent of the cost is paid; the institute's schedule also provides that the owner, in addition to this percentage payment, shall defray the expense (amounting to about 1 per cent of the total cost) involved in securing special expert service covering structural engineering and mechanical engineering, which latter includes power plant, heating, ventilating and electrical engineering (all of which items are included in the 4.50 per cent above mentioned), also the expense involved in the continuous service at the building site itself, of a clerk of works or superintendent of construction, which corresponds to our expense for inspection.

It appears, from this last statement, that the Department of Engineering is doing the work at a cost more than 2 per cent less than the minimum fee established by the American Institute of Architects; there is no reason, however, why the Department should be expected to do the work properly and keep the cost below the fees charged in private practice.

The state should have the best work in architecture as well as along all other lines. The Division of Architecture is securing this kind of work about as follows:

A full appreciation of the building needs of the various state institutions is secured by frequent consultation with the executive heads and boards of management and by frequent visits of the State Architect and his assistants to the institutions.

The designers in charge of the planning and designing of the buildings, from having been in the state's employ for a considerable length of time, have become specially expert as to the building needs of the state institutions and the best methods of meeting them.

An ample force of draftsmen, architectural, structural, mechanical and electrical, is employed, with the result that working drawings, large scale drawings and full size details, as the basis for bids and contract, are thoroughly complete; this is true also of the specifications which form a part of the basis for bids and contract; the specification writers keep in continuous touch with the market as to all building materials. Since our mechanical and electrical engineers, structural designers and specification writers, also our cost estimators, work in conjunction with our architectural men, all employees being under the continuous charge of the heads of the several departments, we are especially well situated to secure perfect and complete sets of working drawings and specifications with a minimum of lost motion.

Our drawings more clearly delineate all the details of construction than the drawings which the average architect provides, and on account of the clearness of our drawings and specifications, bidders are able to estimate more closely the cost of the work; the lower bids run very close to each other in practically every case.

The above conditions as to drawings and specifications, taken together with the continual presence at building sites of competent inspectors, make it possible for us, with the least friction and expense, to secure the completed buildings in accordance with the contract agreements. We are greatly assisted in securing this result on account of the services of our testing engineer, who cares for the analysis and testing of materials entering into the construction of buildings, where such analysis and test are necessary to eliminate doubt as to whether quality and combinations of materials agree with specification requirements.

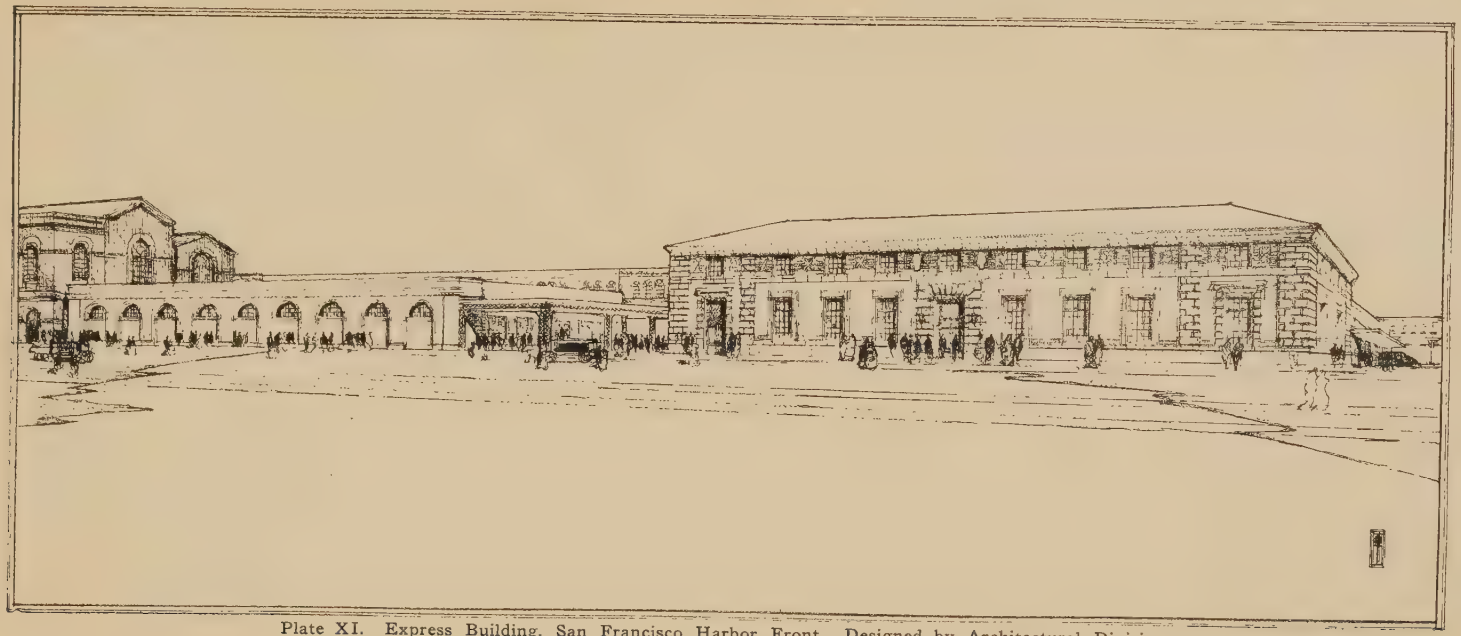


Plate XI. Express Building, San Francisco Harbor Front. Designed by Architectural Division.

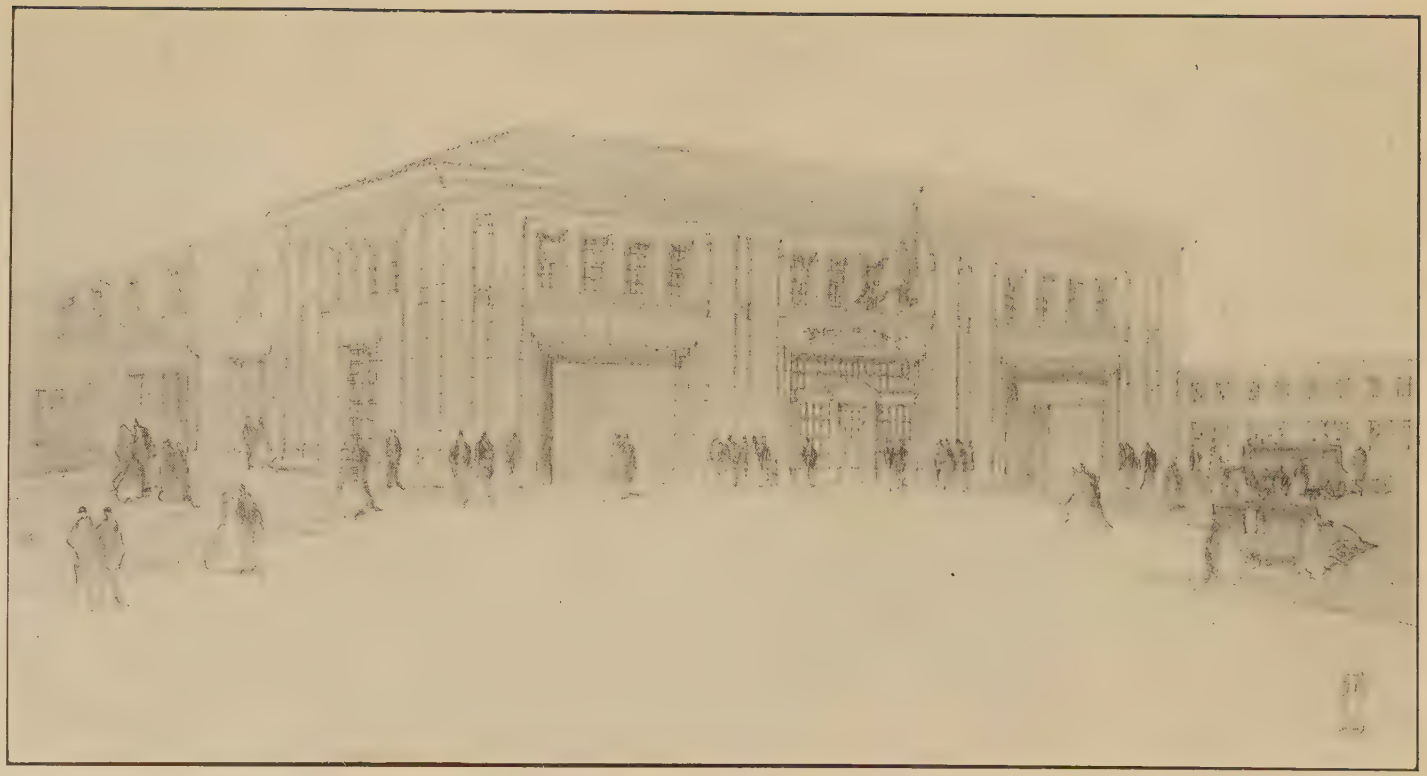


Plate XII. Post Office Building, San Francisco Harbor Front. Designed by Architectural Division.

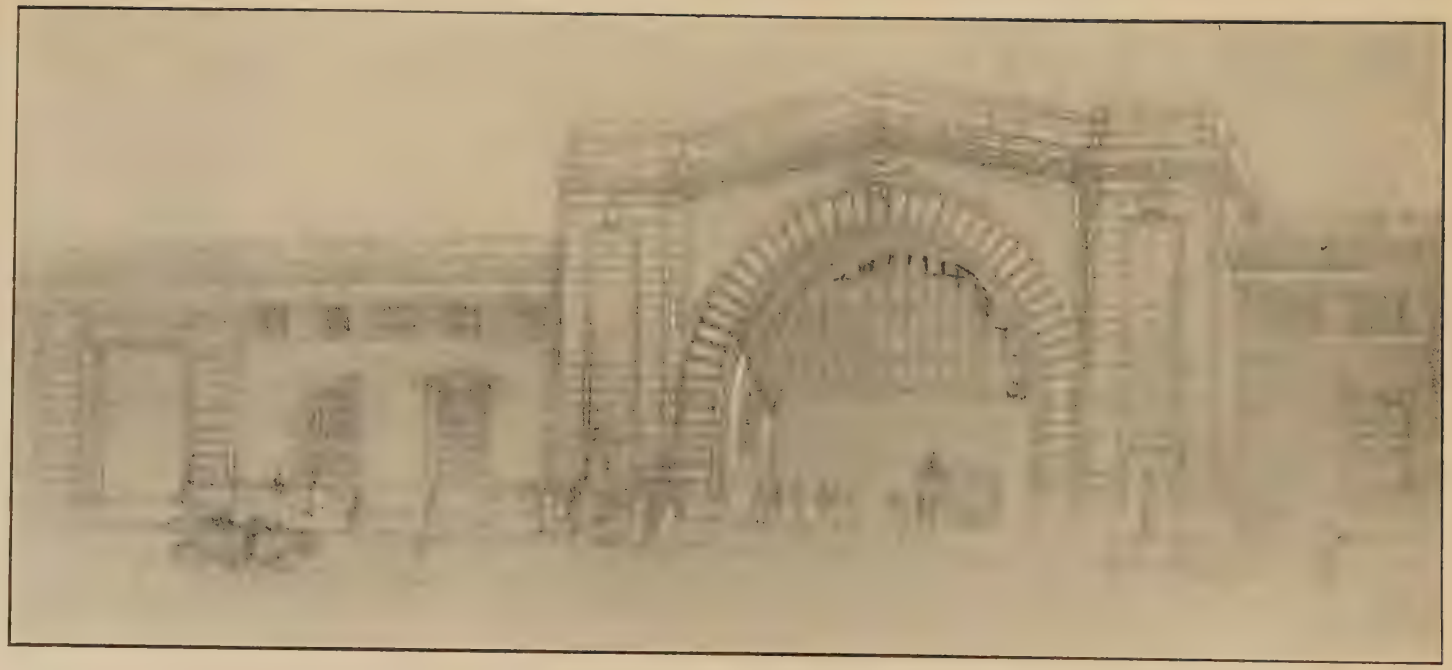


Plate XIII. New Pier Entrance, San Francisco Harbor Front. Designed by Architectural Division.

Following is the partial list of construction hereinabove mentioned, with the total cost of each and the percentage of expenditure for architectural services in the office, and inspection in the field:

TABLE

Partial List of

Building	Location
Nurses' Home—female	Agnews State Hospital, Agnew
Temporary Cottages for males	Agnews State Hospital, Agnew
Workers' Cottage—female	Agnews State Hospital, Agnew
Dairy Barn	California School for the Deaf and the Blind, Berkeley.
Gymnasium	California School for the Deaf and the Blind, Berkeley.
Hospital and Typical Cottages, Nos. 1 and 2	California School for Girls, Ventura
New Conservatory	Capitol Park, Sacramento
Open Air Schoolroom	Chico State Normal School, Chico
Laundry	Folsom State Prison, Represa
Shop Building	Folsom State Prison, Represa
Warden's Residence	Folsom State Prison, Represa
Fresno Normal School	Fresno Normal School, Fresno
Dormitory	Industrial Home for Adult Blind, Oakland
Cottage for tubercular patients	Mendocino State Hospital, Ukiah
Farm Cottage	Mendocino State Hospital, Ukiah
Dairy Buildings	Napa State Hospital, Napa
Six cottage units Chambers Cottage. Dozier Cottage—female.	Napa State Hospital, Napa
Dormitories and sheds	Napa State Hospital, Napa
Laundry	Napa State Hospital, Napa
North Pay Cottage—alterations	Napa State Hospital, Napa
Recreation Hall	Napa State Hospital, Napa
Dormitory	Preston School of Industry, Preston
Trades Building	Preston School of Industry, Preston
Guards' Cottages	San Quentin State Prison, San Quentin
Dormitory for female employees	Sonoma State Home, Eldridge
Cottage for epileptic girls	Sonoma State Home, Eldridge
Nursery Building for males	Sonoma State Home, Eldridge
Cottage for tubercular patients	Sonoma State Home, Eldridge
Four cottages, J, K, L, and M	Southern California State Hospital, Patton
Laundry	Southern California State Hospital, Patton
Cottage H	Southern California State Hospital, Patton
Cottage I	Southern California State Hospital, Patton
Dairy Barns	Stockton State Hospital, Stockton
Ward 25	Stockton State Hospital, Stockton
Recreation Hall	Veterans' Home of California, Yountville
Dairy Buildings	Veterans' Home of California, Yountville
Conservatory	Whittier State School, Whittier
Dairy Barns	Whittier State School, Whittier
Hospital and Receiving Building	Whittier State School, Whittier

On the 13 constructions in above list, costing between $1,000.00 and $12,500.00, the percentage of expenditure for office work was 5.67; for inspection was .41.

On the 10 constructions in above list, costing between $12,500.00 and $20,000.00, the percentage of expenditure for office work was 5.11; for inspection was .91.

On the 11 constructions in above list, costing between $20,000.00 and $50,000.00, the percentage of expenditure for office work was 4.19; for inspection was .92.

On the 5 constructions in above list, costing over $50,000.00, the percentage of expenditure for office work was 3.71; for inspection was .41.

1.

Construction.

Cost	Per cent office work	Expended for office work	Per cent field inspection	Expended for inspection	Total per cent	Remarks
$40,000 00	4.71	$1,924 43	1.33	$545 21	6.04	Under construction.
32,000 00	3.10	989 85	.31	98 00	3.41	Under construction.
50,000 60	4.87	2,487 29	.72	266 65	5.59	Under construction.
5,560 00	7.18	401 37	-------	-------	7.18	Sketches made twice.
50,000 00	5.29	2,500 00	.37	188 00	5.66	Under construction.
85,000 00	4.81	4,087 72	.10	89 00	4.91	Under construction.
3,354 00	12.89	465 96	-------	-------	12.89	Drawings covered a future extension.
1,000 00	11.85	118 57	-------	-------	11.85	Involved putting second story on existing one-story structure.
14,000 00	4.34	607 65	-------	-------	4.34	Construction not started.
33,060 00	.32	108 00	-------	-------	.32	Drawings not complete.
26,000 00	7.92	2,060 65	-------	-------	7.92	Partially complete.
370,000 00	3.80	14,071 83	.02	6 90	3.82	Construction not started.
48,909 00	3.99	1,950 37	1.46	713 80	5.45	Practically complete.
4,073 00	4.28	174 53	-------	-------	4.28	Practically complete.
13,627 00	5.14	791 66	1.69	346 87	6.83	Complete.
18,881 00	3.19	601 50	1.80	326 42	4.99	Complete.
25,000 00	6.81	1,704 58	.96	238 86	7.77	One cottage under construction; drawn twice. Balance of cottages completed.
10,000 00	5.63	563 60	1.04	104 83	6.67	Three different small constructions, one remodeling an existing building.
18,000 00	5.21	935 84	2.59	450 54	7.80	Numerous additions made during construction.
9,438 00	9.69	914 74	3.07	289 75	12.76	Remodeling and adding to existing building.
12,850 00	7.45	957 43	.90	116 20	8.35	Numerous changes made during construction.
3,765 00	2.49	133 33	-------	-------	2.49	Complete.
20,000 00	.81	162 38	.07	7 95	.88	Drawings not complete.
25,000 00	3.09	771 77	3.31	712 27	6.40	Ten somewhat different small cottages.
5,000 00	.46	23 00	-------	-------	.46	Under construction.
17,500 00	8.41	1,565 25	-------	-------	8.41	Drawn twice; under construction.
17,424 00	5.95	1,036 73	-------	-------	5.95	Complete.
2,614 00	2.69	70 43	-------	-------	2.69	Construction not started.
80,000 00	.72	578 46	1.16	932 98	1.88	Four similar buildings.
18,000 00	5.79	1,021 71	1.00	181 10	6.79	Practically complete.
27,230 00	2.78	758 12	1.47	398 58	4.25	Complete.
27,230 00	2.92	792 32	1.57	426 87	4.49	Complete.
18,000 00	5.22	924 72	.18	160 00	5.40	Under construction.
53,980 00	4.59	2,464 85	2.45	1,308 35	7.04	Practically complete.
11,130 00	2.65	293 84	-------	-------	2.65	Drawings not complete.
7,500 00	6.40	478 15	-------	-------	6.40	Complete.
2,190 00	1.97	43 14	-------	-------	1.97	Complete.
4,650 00	6.56	305 68	-------	-------	6.56	Complete.
26,100 00	5.90	1,536 93	-------	-------	5.90	Under construction.
$1,238,471 00		$51,378 40 4.14% of cost		$7,749 13 .51% of cost		

SAN FRANCISCO HARBOR FRONT.

The harbor front of the city of San Francisco is state property, and the administration of it is vested in a Board of State Harbor Commissioners.

The construction, maintenance and operation of all buildings, docks, slips, wharves, a belt railroad along the front, etc., is under the jurisdiction of the board, which reports directly to the Governor.

All engineering, including design, construction, etc., is by law vested in the Department of Engineering and one Assistant State Engineer and one engineering draughtsman are assigned to the Board.

During the last two years Mr. Jerome Newman has been in charge of all work in the harbor front, the details of which are set forth in his report, as follows:

Report of work executed on San Francisco Harbor Front July 1, 1912, to June 30, 1914, under the direction of Jerome Newman, Assistant State Engineer, Engineer in charge.

At the end of the last biennial period, June 30, 1912, four contracts had been awarded for the construction of five new piers numbered, respectively, piers 17, 26, 28, 30 and 32. At the time of my appointment, active work had been begun on pier 17 and the twin piers 30 and 32 only, the former being 24 per cent and the latter 4 per cent completed. All these piers have since been finished essentially as planned and placed in service, the only modification having been in the design of the outer portion of pier 17, by the substitution of cement grout as a filling between the wooden piles and the concrete cylinders enclosing them in place of sand as originally planned.

The layouts which had been tentatively adopted for the improvement of the northern portion of the water front from Lombard street to Fisherman's Wharf and of the southern portion between Mission and Harrison streets were revised and formally adopted and the preparation of plans in accordance therewith was carried on, but owing to unfavorable financial conditions and the impossibility of disposing of the balance of the bond issue, construction could not be commenced with vigor. A few contracts were let, but the general plan of improvement could not be taken up in earnest until the beginning of 1914; since that time, however, the work has been pressed and an energetic effort is being made to put the water front in condition to handle the expected large increase in traffic consequent upon the opening of the Panama Canal.

As the Engineering Division embraces several subdivisions, it will be necessary to report on the work of each separately, as follows:

1. Construction, seawall, piers and wharves.
2. Maintenance and repairs.
3. Belt Railroad.
4. Ferry slips and buildings.
5. Street work and maintenance.
6. Electrical Section.
7. Dredging.
8. Testing Section.

1. Construction.

Seawall, sections 9A and 9B. Section 9A of the seawall is 990 feet long and extends southerly from the end of section 8 near the foot of Mission street to the foot of Folsom street; section 9B is 780 feet long, extending from the southerly

Plate XIV. Pier 26, San Francisco Harbor Front.

end of section 9A, at the foot of Folsom street to the northerly end of section 9 at the foot of Harrison street.

Both these sections are of the same type and differ in several respects from sections 8 and 9. The crest of the rock wall is higher and is placed at the curb line of The Embarcadero, 60 feet back of the water front line, instead of 27 feet as in section 9, giving greater depth of water at the edge of the bulkhead, and, as the concrete retaining wall is located at the crest of the rock embankment, affording the additional advantage of a uniform foundation for the bulkhead pavement. This uniform foundation will prevent the unequal settlement which has been observed in bulkheads built on the type of section 9 in which the outer 27 feet of the pavement rests on the concrete slab and the inner 33 feet on an earth fill.

The concrete retaining wall is much smaller in section than those used in sections 8 and 9 and is carried down to 13 feet below city base instead of 30 feet as in the two latter sections, making it possible to deposit all concrete in the dry instead of placing some of it under water as was necessary in sections 8 and 9. The bottom rests on wooden piles cut off at low water and surrounded by rock, and consequently not liable to decay or attack by marine borers.

The deck is supported by reinforced concrete piles 16 inches square, driven through the rock embankment; in order to avoid shattering the tips, it was found necessary to shoe the piles.

On account of the mud bottom on which the rock wall rests, it was considered advisable to make provision for possible future settlement by constructing the deck of the bulkhead wharf of steel beams carrying a plank and asphalt pavement; the deck can later be raised if necessary, the steel concreted and the planking replaced by a concrete slab.

Section 9A is 76½ per cent completed at the present time, and it is expected that both sections will be finished by January 1, 1915. When completed there will be a continuous line of seawall from Mission street to the north line of Channel street extended and as stipulated in the China Basin lease the outer 100 feet of the thoroughfare along China Basin will be placed under control of the state.

Piers and bulkhead wharves. Before proceeding with the preparation of plans for new piers, the question of the proper class of construction to be employed was thoroughly discussed and it was decided that the use of creosoted piling in certain cases would be preferable to the exclusive use of reinforced concrete, which latter has been used, where deemed practicable. There were several reasons for making this decision, viz: the great depth of mud along the water front from the foot of Harrison street to the foot of Grant avenue, entailing excessive cost of construction in concrete on account of the depth and difficulty of foundations, the urgent necessity of being prepared for the opening of the Panama Canal in the very near future, the constant changes in vessels and freight-handling methods bringing with them the possible need of early reconstruction to meet new conditions, coupled with the great expense of such reconstruction in a concrete pier, and last, but not least, the uncertainty among engineers regarding the probable life of reinforced concrete structures in sea water. It may be remarked that the choice of creosoted pile construction in certain localities agrees with the recommendation to the Maritime Affairs Committee of the San Francisco Chamber of Commerce by a commission of engineers appointed by it for the purpose of examining conditions and reporting thereon.

Observations at the northern portion of the front disclosed the fact that there was a strong tidal current at this point, which might endanger wooden pile structures and it was decided to build the three most exposed piers of the seven contemplated for this section of concrete, to act as breakwaters and to deflect the current eastward away from the shore. For this reason piers 29, 35 and 39 have been designed as reinforced concrete piers, piers 29 and 39 as concrete cylinder piers, resting on wooden piles below the mud line, and pier 35 as a pile pier; and the completion of pier 39 has demonstrated that the object has been attained.

Wherever possible, shipping men were consulted on the most advantageous arrangement of piers, location and character of tracks, sizes of doors, width of slips, etc., and designs were prepared in accordance with their suggestions. All new piers are pro-

vided with at least one track and where width permits with two, one surface and one depressed, the latter being generally placed on the northerly side, and provision is made for the possible future installation of cranes for handling freight by building the substructure and shed columns heavy enough to carry them. Doors are of ample size, usually 22 feet high and 20 feet wide and are equipped with steel rolling shutters which possess the advantages of easy operation, durability and low maintenance cost.

Wherever necessary, the contract for a new pier has included the reconstruction of the adjacent bulkhead wharf either in timber or concrete, depending on circumstances. The wharf connecting with pier 49 is of creosoted piling, those connecting with piers 15, 30 and 41 are of reinforced concrete.

Creosoted pile fenders protected by untreated Oregon pine sheathing have been employed in place of the untreated fender lines heretofore used and wood block pavements in the driveways of wooden piers have been substituted for planking. A large percentage of the total cost of repairs is expended on fenders and planking and it is certain that even with the increased first cost, the above changes will result in materially decreased annual cost, the creosoted piling having ten to twelve times the life of untreated piles and the block pavement four to five times that of planking.

To add to the attractiveness of the front, the old ugly type of shed front was abandoned and the pier fronts south of Market street are to be built in modified mission style, those north of Market street being designed on the lines of the Chelsea piers of New York.

Pier 39. This pier is 140 feet wide, its length on the westerly side being 879 feet and on the easterly side 938 feet, the difference in the lengths of the sides being due to the inclination of the pier at an angle to the seawall. The substructure consists of reinforced concrete cylinders 3 feet and 3½ feet in diameter, carried down from ten to fourteen feet below the dredge line and supported on wooden piles. The deck construction is of the usual transverse girder, longitudinal beam and slab type with a center driveway and a railroad track on each side of the pier, the easterly one being flush and the westerly one depressed. The pavement is Ohio wood blocks in the driveway and asphalt on the remainder of the deck. The fenders are of the suspended type, the same as those used on the new piers at the south end.

In addition to the pier, the contract included the construction of two adjacent sections of reinforced concrete bulkhead wharf, 44 feet wide and extending back of the pier and 144 feet westerly and 175 feet easterly therefrom. The rock wall at this point, having been built in 1878, and being consequently thoroughly compacted without danger of further settlement, was repaired where necssary and concrete piles driven through it, supporting a reinforced concrete deck paved with asphalt. The retaining wall is 16 inches thick and is carried down to 9 feet below city base.

Plans for a two-story steel and concrete shed with a bulkhead building projecting to within 15 feet of the curb line have been prepared; this shed is arranged with offices, waiting rooms, baggage chutes, elevators, etc., for the accommodation of passengers, for which service the pier may ultimately be used. For the present it will be used for the grain sheds.

Pier 39 was completed May 7, 1914, and a contract was let for moving the grain shed from the bulkhead wharf nearby to serve as a temporary shed on this pier until the permanent structure is erected.

Pier 46. This pier is 800 feet long by 200 feet wide and is constructed of creosoted piling, carrying a timber deck with two surface tracks. The design is of the ordinary type and there are no features of special interest.

The pier shed is of timber with sliding wooden doors, 22 feet high and 20 feet wide and with a center driveway. The deck planking consists of a layer of Oregon pine with a wearing surface of cedar.

In connection with this contract considerable work has been done in placing the adjacent bulkhead wharf in good condition.

Pier 46 was 46 per cent completed on June 30, 1914, and is expected to be entirely finished about September 15.

Pier 54. This pier was built in 1910 on a rock ledge extending under a part of the pier and the northerly and southerly slips, and it was found necessary before the structure was completed and accepted to blast the rock on the northerly and

Plate XV—A. Piers 30 and 32, San Francisco Harbor Front.

B. Pier 26. Interior, San Francisco Harbor Front.

C. Piers 26, 28, 30, 32, San Francisco Harbor Front.

southerly sides to the dredge line, in order to afford sufficient depth to accommodate vessels berthing alongside. A contract for the blasting had been let in June, 1910, and this was carried on while the pier was building, a work attended with much difficulty and some danger to the outside row of cylinders supporting the pier. It was finally decided to leave a ledge 6 feet wide outside the north row of cylinders where the rock was hard and chisel out the rock beyond the ledge until a sufficient distance had been reached to render blasting safe; the entire area over which the rock was present was then blasted out to the dredge line.

On account of the ledge which was left on the north side, it was not possible to dock vessels with safety and an extension 10 feet wide was built along the entire length of this side, this extension being supported on reinforced concrete piles set on the rock ledge for the outer 441 feet and on creosoted piles driven into the mud for the inner 339 feet. The deck on the concrete pile section consists of reinforced girders and beams carrying a slab and that on the creosoted pile section is of timber covered with plank. The deck on both sections is securely bolted to the original structure and the entire area is paved with asphalt. The extension was completed on June 30, 1914.

Pier 41. This pier is 200 feet wide, its length on the westerly side being 881 feet and on the easterly side 1,081 feet. It is supported on creosoted piling, has a timber deck with two surface tracks, and is paved along the driveway in the center with bituminous concrete and on the sides in the cargo space with asphalt. The fender line consists of creosoted piles protected by untreated Oregon pine sheathing extending to below low water.

This pier is an open one and it is not intended to erect a shed on it. It is intended to be used for lumber, steel beams and all kinds of bulky cargo.

In connection with the pier there is to be constructed under the same contract a section of reinforced concrete bulkhead wharf back of the pier and 149 feet easterly therefrom; this is identical in design with the wharf adjoining pier 39.

Pier 41 was 21 per cent completed on June 30, 1914, and is expected to be finished about December 1, 1914.

Pier 15. This pier, which is to replace the old one at the same place, condemned on account of its dangerous condition, is 794 feet long and 90 feet wide. It is a creosoted-pile pier with timber deck having one surface track located near the center to serve the coal bunkers on the southerly side, with a pavement of cedar plank on the driveway under the coal bunkers and of bituminous concrete outside the bunkers. The fender line is constructed of creosoted piles with untreated Oregon pine sheathing.

The northerly half of the pier is to be built first and the coal bunkers moved temporarily to this portion when completed, after which the southerly half will be constructed and the bunkers then moved to their permanent location on this portion. There will be no shed, none being needed.

The contract for this pier includes the building of a section of reinforced concrete bulkhead wharf back of the pier and 101 feet northerly, having a width of 41 feet and supported on reinforced concrete piles driven through the old rock seawall. There is a concrete retaining wall at the inside, carried down to 13 feet below city base and resting on wooden piles also driven through the seawall. The deck is of the usual girder, beam and slab type and is paved with asphalt.

Pier 15 was 6 per cent completed on June 30, 1914, and will probably be finished about January 1, 1915.

Pier 27. An extension 12 feet wide was constructed along the entire northerly side of this pier for the purpose of carrying a surface track. This extension is supported on creosoted piles and has a planked timber deck. Under the same contract, extensive repairs were made to this pier and the adjacent bulkhead wharf, which will be described under "Maintenance and repairs." The extension to pier 27 was completed March 19, 1914.

Pier 25. An extension 14 feet wide was constructed along the entire southerly side of this pier to carry a surface track; this is similar in design to that used on pier 27. It was completed on April 30, 1914.

Miscellaneous. The outer 337 feet of Sixteenth street wharf was brought out to full width by building a 77-foot extension on the northerly side; this was completed February 6, 1913.

A creosoted pile bulkhead wharf 290 feet long with an average width of 110 feet was built in front of section 8 of the seawall and was completed January 2, 1913. This was designed for temporary use during the construction of the seawall south of Mission street.

A creosoted pile bulkhead wharf 411 feet long and 60 feet wide to accommodate government vessels and lumber schooners is in course of construction north of Fisherman's Lagoon and will be completed in one month.

Projected work. Plans have been prepared or are in course of preparation as follows:

New piers, numbered 16 and 18, to be located between Howard and Folsom streets; these plans are completed and contracts may be let as soon as possible.

Piers 35 and 37, located respectively at the foot of Montgomery street and the foot of Kearny street; these are 80 per cent completed.

Piers 22 and 24, located near the foot of Harrison street; these have just been begun.

Seawall extending from Jones street to Larkin street; instructions have been given to prepare these plans and in connection therewith to provide for the removal of Fisherman's Lagoon to the blocks north of Jefferson street, between Hyde and Larkin streets.

2. Maintenance and repairs.

The ordinary repairs to piers, bulkheads and ferry slips have been made by the state force, but some large jobs amounting to practical reconstruction of piers were let by contract. In order to determine the relative cost of small work by contract and by day's labor, a comparison was made for one month on the basis of actual work done, taking into account for the state force all pay roll and proper material charges and increase in wages since the contract system was abandoned as against prices paid for contract work in 1910–1911. The comparison showed a saving of 35 per cent, and this would justify the adoption of the present system if no other reason existed; it may, however, be accepted as a fact that work done by forces under the direct control of those who pay for it is of better quality than that done by contractors and the conclusion is warranted that the day's labor system now in use for small repairs results in better work at a lower cost than the contract system.

Disintegration of concrete supports of five piers. In order to ascertain whether repairs were necessary, piers 19, 21, 23, 25 all constructed in 1901, and pier 27 constructed in 1907, all of which are supported on cylinders of plain concrete deposited in water and carried only a few feet below the mud line, were examined by divers and their condition found to be as follows:

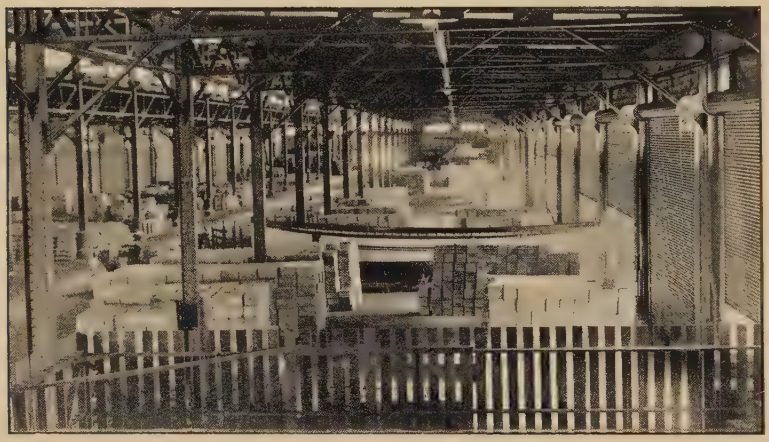
The 234 cylinders under pier 19 contain three piles each; of these cylinders, three had fallen, the disintegration of the concrete in 157 had exposed the piles and 74 were in good condition.

The 234 cylinders under pier 21 contain three piles each; of these cylinders, two had fallen down, the piles in four had been eaten off, leaving them hanging on the caps, the disintegration of the concrete in 166 had exposed the piles and 62 were in good condition.

The 234 cylinders under pier 23 also contain three piles each; of these cylinders, 15 had fallen down, the piles in two had been eaten off, the piles in 140 were exposed and 77 were in good condition.

The condition of the outer 60 feet of pier 25 having become dangerous some four years ago, repairs were made by driving a creosoted pile on each side of the cylinders. There were 274 three-pile cylinders under this pier, of which 18 had fallen down, the piles in twelve had been eaten off, and those in 135 were exposed, the concrete in 22 showed disintegration and 87 were in good condition.

Plate XVI—A. Pier 28, San Francisco Harbor Front.



B. Pier 28, Interior, San Francisco Harbor Front.

C. Pier 39, San Francisco Harbor Front.

Of the 400 one-pile cylinders under pier 27, 58 had disappeared, the piles in 49 had been eaten off, those in 40 cylinders had been exposed by the destruction of the concrete, which had also begun to crumble in 32 others without, however, exposing the piles, and 221 were in good condition.

The results of the diver's examination showed the necessity of making repairs to these five piers and instructions were given to do so. The repairs to piers 25 and 27 were included in the contracts for the spur track extensions previously described and on the completion of these contracts another was let for the repair of pier 19; this last was 12 per cent completed on June 30, 1914, and it is intended to begin work on the remaining two piers as soon as possible.

The repairs are made with creosoted piles which are driven under the timber caps of piers 19, 21, 23, and 25 and in the case of pier 27 carry sub-caps supporting the steel caps of the pier. The defective cylinders are to be loosened and laid on the bottom, care being taken to prevent damage to the piles during the lowering. These repairs will insure about fifteen years' further useful life of these structures, at the end of which time it will be cheaper to tear down and rebuild than to attempt to maintain them.

3. Belt railroad.

A large amount of work has been done on the Belt Railroad, both in the way of additional spurs serving piers and industries and siding and extensions. Mention has already been made of the fact that all new piers are provided with one or two tracks, those completed and under contract being as follows: Piers 46, 32, 30, 28, 26, 37, 39, and 41, two tracks each, and piers 15 and 17 one track each; of those projected, piers 16, 18, 29, 31, 33, and 35 are to have two tracks, while those to be numbered 24 and 22 are to be supplied with one. Spurs have also been constructed to piers 25 and 27, and it is intended to place one later on pier 13.

A decided improvement in operating conditions was effected by the building of that portion of the line crossing the foot of Market street and connecting the northern and southern divisions; this link is 3,900 feet long and extends from Folsom street to Broadway. Some difficulty was experienced in the construction of the section in front of the Ferry Building and extending north to Clay street; The Embaracadero at this point is a sand fill carried by a timber platform supported by piling cut off at low water level, and it was necessary for a distance of 390 feet, where the piles were too far apart to carry trains safely, to trench the street, drive the required additional piles and lay a new plank platform to retain the sand. The entire connection was completed and ready for operation on Jaunary 27, 1913.

The Belt Railroad is being further extended from the foot of Powell street, its former northerly terminus, by the construction of the line to the government transport docks at Fort Mason. This line begins at the corner of Powell and Jefferson streets, and runs westerly along Jefferson street to Van Ness avenue, turning thence to the corner of Beach and Laguna streets and connecting with the government tracks to the transport docks and warehouses and also with the tracks of the Panama-Pacific International Exposition. Between Taylor and Jones streets, where it runs along the southerly edge of Fisherman's Lagoon, and between Larkin street and Van Ness avenue where it crosses the cove east of Black Point, it is on trestle and under the government reservation at Fort Mason, in tunnel. The trestles are open deck, built in accordance with standard railroad practice, having creosoted pile bents and creosoted sway braces and girts; tower bents are spaced every 150 feet. The tunnel is 1,500 feet long, its easterly portal being situated 120 feet west of the westerly line of Van Ness avenue, and its westerly portal 245 feet east of the easterly line of Laguna street. It is concrete lined throughout with a clear width of 17 feet and a clear height above top of rail of 22 feet. At the westerly end from the portal to Laguna street there are concrete retaining walls about 250 feet long, having a height of 27 feet at the portal face and 4 feet at the easterly line of Laguna street; these walls were ordered built to save as much ground as possible for the use of the reservation.

The material encountered in the tunnel was a sandstone shale for the easterly 700 feet, clay in the middle 400 feet and sand in the westerly 400 feet. The easterly and middle portions were excavated by the ordinary heading and bench method, a center shaft being sunk to hasten the work, the westerly section in sand being taken out as an open cut and backfilled after the masonry was completed. The shaly rock from the easterly portion was used to make an embankment extending into the bay from Hyde street to Larkin street, and heavily riprapped along the northerly side and the westerly end to protect it from wash.

This extension which is 1.09 miles long was 47 per cent completed on June 30, 1914, and is expected to be ready for trains by November 1, 1914, in ample time to serve the Exposition.

A reinforced concrete engine house containing seven stalls was erected on seawall lot 8, bounded by Lombard and Sansome streets and The Embarcadero. This building is provided with a drop pit, machine shop, blacksmith shop and storeroom; the engine house proper and the machine shop are floored with wooden blocks on a concrete base, the storeroom with concrete and the blacksmith shop with cinders.

It is expected that this engine house will suffice for the needs of the Belt Railroad for several years and when additional stalls are required another engine house should be built on the southern division. This engine house was completed April 30, 1914.

The total length of line between the north side of Second street wharf, the present southerly terminus and Beach and Laguna streets, the proposed northerly terminus is 3.70 miles. A comprehensive plan has been worked out for the track system between these termini which contemplates 1.86 miles of single track, 0.64 miles of double track and 1.20 miles of three track road, the number of tracks being determined by local conditions of railroad yards and tracks serving industries at different points. The single track sections extend from the north side of Second street wharf to Berry street, from King to Townsend street, from Folsom street to Broadway and from Powell to Laguna street; the double track sections from Berry to King street, from Harrison to Folsom street, from Broadway to Green street, and from Battery to Francisco street, and the three track sections from Townsend to Harrison street, from Green to Battery street and from Francisco to Powell street.

To render possible the storage of cars during the season of heavy traffic, yards have been projected on seawall lots 20 and 18 at the south end and on lots 1, 2, A and B at the north end; these yards will assist materially in doing away with congestion of the main line and in assuring rapid delivery of cars to shippers and to the different railroad companies entering the city. Several of the tracks planned for these yards have already been laid.

4. Ferry slips and buildings.

Passenger ferry slips. Plans for new passenger slips at the north and south ends of the ferry system have been prepared, those at the north end being designated A and B and those at the south end being numbered 7, 8, 9 and 10; of these, slips B, 8, 9 and 10 are to be entirely new and slips A and 7 are to be partially rebuilt to fit the enlarged system.

The dolphins are to be constructed of creosoted piles carrying a timber deck covered with a double layer of planking at the outer end and with a single layer paved with asphalt on the inner portion. While the general type of construction is similar to that used in the older slips, several improvements have been made, such as strengthening the aprons to permit the passage of loaded trucks weighing 20 tons and reinforcing the noses of the dolphins and the clusters at the outer ends of the aprons with the object of reducing the liability to damage at these points, the most vulnerable parts of the fender line. The older aprons were capable of carrying a 12-ton vehicle, but as loads have increased since the general adoption of the auto truck, shippers who desired to send heavy machinery, etc., across the bay were put to serious inconvenience and expense on account of the limited capacity of the aprons and to meet their wishes, the heavier aprons have been designed. The noses of the new dolphins are more heavily piled than other portions and are strongly

braced transversely by continuous lines of timbers fastened to the piles and extending entirely across the dolphin, these timbers being placed both above and below the deck and bearing against the ribbons of the spring line. The clusters contain 19 piles as against 9 formerly. It is expected that these changes will result in decreasing repairs, as the nose and cluster are more subject to damage by ferry boats than any other part of the spring line and consequently oftener in need of repairs.

The end dolphin on the southerly side of slip 10 is to be of larger size than any of the others, its average length, measured from the water front line, being 670 feet and its width at the outer end 120 feet; it is to carry a shed 110 feet wide by 430 feet long intended for express purposes. The berthing space of 650 feet on the southerly side of this dolphin makes this a particularly favorable location for small boats and launches and a space 60 feet wide outside the shed has been left for use of the business of these vessels. The end dolphin on the northerly side of slip B has a berthing space of 465 feet with a width at its outer end of 66 feet.

Foundations for upper deck aprons have been provided at all slips and contracts for these, wherever necessary, can be let after the completion of the slips.

Slip 8 was completed June 25, 1914, and contracts for slips 7, 9 and 10 will be let in the near future, in time to insure their being available for use before the opening of the Panama-Pacific International Exposition.

Car ferry slips. The present car ferries at the foot of Lombard street are to be torn out to make room for piers and two new ones are being built between the foot of Powell street and the foot of Taylor street. They are of creosted piles carrying a timber deck planked with Oregon pine, which on the eastern dolphin is covered with a wearing surface of cedar to permit of teaming when this dolphin is used for berthing vessels. The construction follows the plan of the present car ferry slips in general but with steel aprons and wider dolphins supplied with more tracks, there being two of these on the easterly dolphin, four on the middle one and two on the westerly dolphin.

In connection with the contract for the car ferry slips, the adjacent bulkhead is being reconstructed to carry tracks, this work being carried out in timber on the same plan as the slips. The car ferry slips were 4 per cent completed June 30, 1914.

Buildings. Plans for buildings in the vicinity of the ferry slips are being prepared as follows:

Extension to the southerly end of the main Ferry Building to be used for baggage purposes.

Post office building to be located opposite the foot of Mission street with a connecting shed on the dolphin between slips 8 and 9.

Shed on the dolphin on the south side of slip 10 to be used for express purposes.

The Ferry Building extension is to be a one-story structure 140 feet wide by 126 feet deep, carrying out the arcade treatment of the first story front of the main building. It is to be of frame construction with plastered exterior, the latter being painted to match the stone of the Ferry Building. There is to be a light steel frame shelter at the southern end for teams handling baggage and a two-story steel frame and concrete structure behind the extension for the gangways for passengers to and from the upper and lower decks of ferryboats. The extension is to be supported by creosoted piles with a wooden floor, the rear gangways being carried on concrete piles with a concrete deck paved with asphalt.

The Ferry Building as originally designed included a wing at each end, which for lack of funds were not built. Ultimately, but probably not for some years, they will doubtless be added and will be of the same stone as the present structure. For this reason the one-story extension for baggage-room purposes now in progress being only temporary in character, is of frame and plaster construction.

The interior is to be arranged for use by the Southern Pacific Company and the Western Pacific Railway. In connection with the erection of this addition, a part of the present baggage room at the southern end of the Ferry Building is to be remodeled to provide waiting room space for the Western Pacific.

The post office is to be 167 feet wide by 125 feet deep on the first floor with a second story extending the full width of the building and 58 feet deep. The construction is to be steel frame with brick walls, carried by concrete piles and a concrete deck paved with asphalt. The first floor is to be divided into workrooms for handling mail with the necessary space for the public, and the second floor is to contain offices for the use of the office force. In addition there will be four mezzanine floors provided with lockers, etc., for the working force.

Connected with the main post office, there will be a timber shed containing an area of approximately 16,000 square feet and divided into workrooms and storage spaces; this shed is to be built on the dolphin between ferry slips 8 and 9. The two-story steel and concrete gangway in the rear of the Ferry Building extension is to be continued to the southerly end of the post office and from this point a one-story structure is to be built over the passageway to the extreme southerly ferry slip.

The shed intended for Wells, Fargo & Co. is to be 110 feet wide by 430 feet deep on the first floor with a second story 202 feet deep across the entire width of the building; the construction is to be wood frame with plastered exterior. The lower floor is to be used for general office and workroom purposes, the second floor being intended for the clerical force and for sorting and distributing express matter.

5. Street work and maintenance.

Besides the ordinary repair work done on The Embarcadero by Harbor Commission forces, considerable new work has been done by contract during the last two years in connection with improvements ordered by the San Francisco board of supervisors on streets bounding property belonging to the state. The different contracts of this character which have been awarded are as follows:

Paving the easterly half of Beale street between Bryant street and The Embarcadero, completed in April, 1913.

Sewering Bryant street between Beale and Main streets, completed in May, 1913.

Paving the southerly half of Brannan street from First street to The Embarcadero, completed in June, 1913.

Sewering Steuart street between Folsom and Harrison streets, completed in July, 1913.

Sewering and paving the southerly half of Bryant street between Main and Spear streets and the easterly half of Spear street from The Embarcadero to near Harrison street; this has not yet been completed.

In addition to those enumerated above, a contract has been let for sewering and paving The Embarcadero from pier 24 to pier 26, which was about 2 per cent completed on June 30, 1914, and it is intended to extend this pavement northerly as soon as feasible. Contracts will also be awarded for sewering and paving Fremont street from The Embarcadero to Brannan street, and Main street from The Embarcadero to Bryant street; the property fronting on both sides of these streets is under control of the state and plans and specifications will be prepared in this office and the work done under our direction.

On account of the increasing traffic along the water front, especially at the southerly end, it is highly desirable, in order to avoid congestion, that all streets leading into The Embarcadero be improved and the work enumerated above has been of material benefit in this respect.

6. Electrical division.

The work of the electrical department during the past two years has been varied and extensive, numerous improvements in the lighting of piers and ferry slips having been effected and considerable progress made in placing wires underground.

The electric lighting system along The Embarcadero has been extended from pier 34 northerly to Harrison street and from pier 11 northerly to pier 27 by the installation of 39 additional electroliers equipped with 250-watt and 400-watt tungsten lamps. Conduits, wires and post holes are being placed in sections 9A and 9B of the seawall

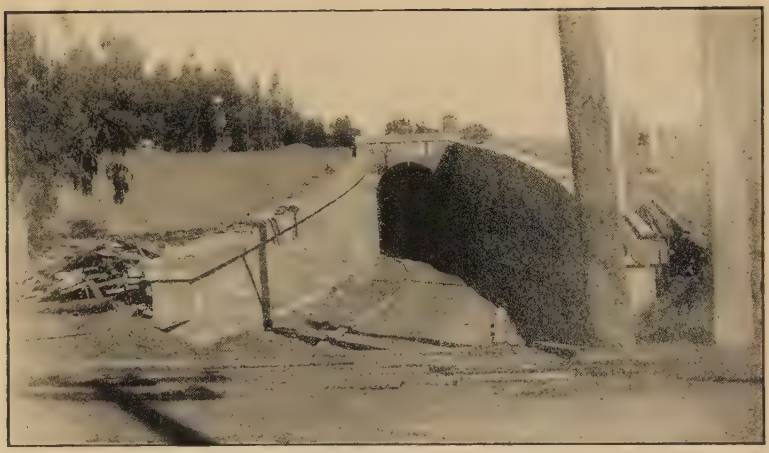
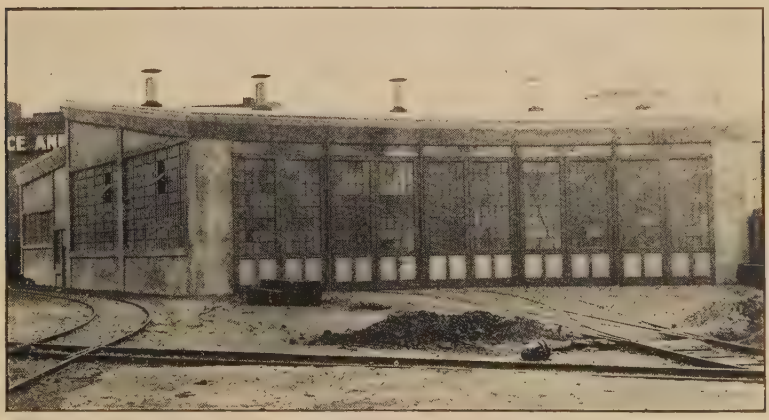


Plate XVII—A. Belt Line Railroad Tunnel, West Portal, San Francisco Harbor Front.

B. Belt Line Railroad Tunnel, East Portal, San Francisco Harbor Front.



C. Belt Line Railroad Roundhouse, San Francisco Harbor Front.

and bulkhead wharf now under construction, and when these are completed there will be a continuous system of high efficiency electroliers, 110 in all, from Channel street northerly to Lombard street.

The problem of proper pier illumination has been the subject of study with the purpose of obtaining maximum efficiency with minimum cost. As a result of data obtained from trial installations, the large wattage Mazda lamp was adopted and this is replacing the arc lights formerly used; all but five of the piers have been equipped with the modern lamps and the changes on these piers will be made in a short time. The improvement in lighting due to these changes, with its accompanying economy, has met with the hearty approval of shipping men.

An underground conduit system for Harbor Commission wires has been planned from Channel street to Lombard street; of this, the section from the Channel to Harrison street has been completed. Conduits are being placed in sections 9A and 9B of the new seawall and the section from the Ferry Building to Lombard street is about 85 per cent finished. A manhole is to be built opposite each pier entrance from which conduits and service wires are to be led into the sheds.

Notice has been served on electric public service corporations to place their wires underground and this is gradually being done, a separate system of conduits being laid for these wires. All poles and overhead wires, with the exception of those owned by the United Railroads, have already been removed from the Ferry Building north to Chestnut street. All private service wires to piers or other state property are to be run into Harbor Commission manholes; the conduits and wires extending from the latter are owned by the Harbor Commission, thus minimizing inconvenience and delay when the contract for furnishing electricity passes from one company to another.

Five new fire boxes numbered from 934 to 938, inclusive, have been installed on The Embarcadero between Channel and Harrison streets and have been connected with the fire alarm system of the city.

Precautions have been taken to protect the outer ends of exposed structures by installing fog bells and beacons, bells having been placed on piers 46, 32, 26, and 17, all connected with testing apparatus in the Ferry Building to enable the operator to be certain that they are ringing properly and beacons having been established on piers 46 and 39. In addition, new beacons of high power have been installed, one on the main ferry dolphin and another at the top of the tower and all pier head lights along the water front have been replaced by others of greater candle power. A Douglas fog signal of 25,000 candle power has been placed on the main ferry dolphin and a second is to be furnished for pier 39. Safety lights of large candle power have also been installed at every ferry apron and have proved of great benefit during rush hours.

A remote control system has been introduced whereby the street lights from the Ferry Building north to Chestnut street are operated from the main switchboard in the Ferry Building and this will eventually be enlarged to include all Harbor Commission lights from Channel street to Fisherman's wharf.

The time service in the building had become the cause of much complaint on account of the unreliability of the tower clock and the various electric clocks in the offices and waiting rooms. The department investigated the subject carefully, collecting data from terminals in other cities and adopted a modern half-minute jump electric clock system, controlled by a master clock; this system is now being installed. At the same time the Howard pendulum movement in the tower is being replaced by an electric movement designed by this department and controlled by the master clock operating the secondary clocks in the building; this movement was successfully tested for several months under actual working conditions before being installed.

7. Tugs and dredges.

The dredging equipment has been kept busy, not only in maintaining the necessary depth at the older piers, but also in excavating at the new structures wherever necessary before and after completion.

charge his fellow partners an excessive price for the materials which he happens to furnish for the common use and benefit of all, and that any price based upon protection to any individual concern is an excessive price. It also holds that, on account of the character of the state's business as to the absence of risk and the reduction of the selling cost to the lowest possible terms, the manufacturer can afford to sell the state at as low a price as to any other customer, regardless of the quantity purchased. It is gratifying to note that a constantly increasing number of manufacturers agree with the soundness of this claim, with the result that in the case of many articles purchased by the Department competition no longer is confined to the portion of the manufacturer's 10 per cent protection which the various individual jobbers are willing to accept.

The purchasing office, although constantly handling an increasing quantity of business, has been administered with due regard to economy. The office since the beginning of July, 1913, and up to November 30, 1914, handled a total of 8,493 orders, or an average of 21 for each working day. In the eleven months of the year 1914 it handled 6,424 orders, or an increase from a little less than 15 orders a day in the last half of 1913 to nearly 24 orders for each working day throughout the year 1914. The total amount of the business handled amounts to something over a million dollars annually. The operating cost of the purchasing office is approximately $600 a month. Based upon an annual business of one million dollars, the purchasing cost is a little less than eight tenths of 1 per cent.

PART II

Hydroeconomics

Plate XVIII. Oldest Dam in California—1787, Nine Feet High. (Courtesy H. B. McGlashan, U. S. Geological Survey.)

Plate XIX. The Newest Dam in California—1914, 280 Feet High. (Courtesy Pacific Gas and Electric Company.)

HYDROECONOMICS.

SACRAMENTO RIVER PROBLEMS.

Long ages ago, as measured by man's brief units of time, but at a comparatively recent period in the geologic history of California, probably in the later centuries of the glacial period, lapping over from the Pleistocene age to the early part of the Quaternary, the Great Valley of California, extending from the north end of the Sacramento at or near Iron Canyon to the south extremity of San Joaquin Valley at Tejon, was the site of a vast fresh water lake. The word "vast" in this connection is used correctly, as the area of this body of water, more than 17,000 square miles, was equal to that of Lakes Erie and Ontario, combined.

Whether the lake was drained by a sudden seismic cataclysm, or by the gradual wearing down of its outlet to the ocean through a pass in the westward wall between Mount Diablo and Mount Tamalpais, is not clearly revealed, but the latter seems most likely.

Much of the floor of the lake was below sea level, and when the barrier was broken through allowing the waters of the Pacific Ocean to enter the lower portions it became a great bay or sea with arms extending north and south.

By the continual, if slow, accumulation of detritus washed down from the surrounding mountains, the water was driven farther and farther toward the Golden Gate, and the present floor of the two great valleys—the Sacramento and the San Joaquin—was formed by those fluviatile deposits from the highlands.

This great inland sea which stretched along the foot of the Sierra has finally become but a remnant—Suisun Bay, lying just inside the gateway which is now called Carquinez Straits.

The area of Suisun Bay is about 50 square miles at ordinary stages. Contiguous to it originally were 100 square miles of marsh lands covered daily by the tide.

In the deltas of the Sacramento and San Joaquin rivers are more than 500 square miles of land with an elevation of less than ten feet above low tide. The range from low to high tide is about six feet at low stages of the rivers.

The principal islands forming the deltas of the two rivers named are as follows:

TABLE 2.

Sacramento River Delta.

Merritt	4,200 acres
Sutter	2,500 acres
Ryer	11,800 acres
Grand	17,100 acres
Andrus	7,600 acres
Brannan	7,000 acres
Sherman	14,000 acres
Tyler	8,664 acres
Twitchell	3,500 acres

San Joaquin River Delta.

Union	33,000 acres
Roberts	48,000 acres
Rough and Ready	1,600 acres
Lower Jones Tract	5,739 acres
Upper Jones Tract	6,289 acres
Victoria	6,900 acres
Woodwards	2,245 acres
Bacon	6,700 acres
Unnamed	1,400 acres
Unnamed	4,100 acres
Unnamed	3,100 acres
Vandeville	5,700 acres
Frank Tract	3,100 acres
Bethel Tract	3,780 acres
Bradford Tract	2,120 acres
Webb Tract	5,580 acres
Jersey	4,000 acres
Venice	3,875 acres
Bouldin	6,240 acres
Staten	9,300 acres

These islands were all formed by the gradual deposition of fine material brought down from the mountains by the annual floods of the rivers. By the action peculiar to sediment-bearing streams, the banks were built up higher than the surface of the land some distance away, and nearly all of these islands have that characteristic. Being surrounded on all sides by the streams that built them, the borders of the islands forming the banks of the streams are higher than the land at the interior, so that they may be correctly described as being "saucer shaped." The rims of these bowl-like islands were sometimes raised well above tide level, as at the upper end of Grand Island, where the bank was about 14 feet above low tide; and at the head of Roberts Island on the San Joaquin the level of the bank was 18 feet above datum. The lowest point on Grand Island was more than ten feet below low tide and 25 feet or more lower than the rim at the upper end of the island.

Before mining in the mountains had sent untold millions of cubic yards of detritus down the rivers, and before levees had been constructed along their banks in attempts to keep the water off the adjoin-

ing land, the waters of the rivers were free to spread over the floor of the valley whenever they were swollen to a volume larger than the prism between the banks.

As stated above, the banks of silt-bearing streams, are higher than the land at a distance. This condition produces troughs or basins between the rivers and the rising ground of the foothills. The fall from the top of the river bank is sometimes as great as ten feet in a thousand for short distances.

Prior to the commencement of farming on the low lands and the building of protection levees, the high waters ran over the banks, filling the basins to the flood level of the stream and obliterating all trace of the channel, excepting as the banks were marked by the growth of trees.

During the flood of 1853 the conditions are described as presenting to view a "sea of water" from Sutter's Fort (in Sacramento City) westward to where Davisville now is, and southward to Stockton, the water being three feet deep over the banks of the river.

The condition that caused more than one million acres of land to be inundated by the waters of Sacramento River, and as much more by the San Joaquin and its tributaries, was simply the inadequate size of the channels.

Hydraulic mining began to send debris down very shortly after Marshall's discovery of gold in 1848, and naturally great quantities of it were arrested in the channels where the slight gradients reduce the velocity of the water.

Very soon after the miners began washing the hillsides into the rivers, farmers were attracted to the rich lands lying partly submerged on the islands of the river deltas, and began in 1852 or 1853 to build levees to keep the water off the land. The first attempts were at the upper end of Grand Island, where small levees were built to keep off the flood waters from the river. These were extended from time to time along the banks of Old River and Steamboat Slough, until finally the entire island was encircled, not, however, without suffering breaks at different times. Of late years the levees have been so strengthened that they withstood the floods of 1907 and 1909, while the nearby islands were flooded.

The settlement of other islands followed; more levees were built and the river more or less successfully diked off from spreading over the lands. The result of all these changes, filling the river beds with debris and narrowing the channels with encroaching levees, has been to raise the water plane all along the course of the streams.

The Commissioner of Public Works estimated in 1894 that the Sacramento River from the mouth of the Feather to Suisun Bay had been reduced in cross-sectional area one third. Low water stages at Sacra-

mento were then reported to be five to seven feet higher than in 1849.

Prior to the influx of mining debris the influence of tides in Suisun Bay was felt in Sacramento River for several miles above the city of Sacramento, but with the rise of the bed of the river the limit of tidal action gradually receded until for many years no pulsations could be detected in the river above Haycock Shoals, 10 miles below Sacramento.

The depletion through the agency of the annual storms of the stores of mining detritus in the gulches and canyons of the hills coupled with the cooperative efforts of state and nation in works to arrest the flow of debris down the Yuba River have affected the regimen of the main river to such an extent that for several years the water plane has been slowly falling.

Tidal pulsations were reported in the river at Sacramento City in 1902. They became quite pronounced in 1910 and have increased in height until in 1913 there was a daily fluctuation of more than 20 inches recorded by the river gauge of the U. S Weather Bureau. Owing to an unusually large summer flow in the river this year the tidal action is much less marked.

In its original condition the river was not able to carry the flood waters, as was shown in 1853 and 1862. Although the latter date was twelve years after hydraulic mining had commenced, the fact that low water registered 0 on gauge as late as 1856, and in 1861 it was only 1.5 feet is taken to indicate that not much filling had occurred up to that time, and yet, as before stated, the water ran over the banks all along its course, converting the valley into a sea from ten to twenty miles wide.

In attempting to devise any scheme for relieving the situation as it exists in the great valley of California, it is found that the interests of navigation, drainage, flood control, and irrigation are so intimately connected that one can not be discussed without considering the others; and they seem to pair off in antagonisms, although so interdependent. Large reservoirs to intercept the flood are advocated, and could undoubtedly be made to greatly lessen the dangers of the flood waters, but to construct and maintain them without regard to their use for irrigation would not be thought of. Yet, if they are to be useful for the latter purpose, they must be filled with the first water that comes in sufficient quantity, else they may not be filled at all. If they are filled early, then when the flood arrives their capacity to absorb the flood flow is gone. So the one interest is opposed to the other.

Navigation requires a small channel in order to husband the water into a narrow space when the stream is low; flood protection demands a waterway of ample dimensions. Elaborate schemes have been worked out to reconstruct the main channels of the rivers so as to carry ordinary high stages, with overflow structures to take off the surplus

into auxiliary channels, confining it between embankments so as not to flood the lands,—all of these by-passes to converge into the one channel entering tide water.

Another scheme that has been proposed is to dredge the detritus from the river channels, using the material dredged to strengthen the levees on the banks. In the case of the Sacramento River, it has been estimated that the channel from Feather River to Suisun Bay has filled from six to fifteen feet and that from 80,000,000 to 120,000,000 cubic yards of detritus are lodged there. Let all of this be taken out and still the channel will not carry ordinary floods, much less the extraordinary. The river from the vicinity of Colusa to the mouth of the Feather has channel capacity to carry within its banks only about 30,000 second-feet, yet the records show that at Iron Canyon, 60 miles above Colusa, there were, February 3, 1909, 254,000 second-feet flowing. The stretch from Stony Creek, where it has the first opportunity to overflow, to Colusa, the gradient of the river, as determined from the slope of the low water surface, is 1.29 feet per mile, and for the stretch of small channel way, from Colusa to Feather River, the fall is only 0.34 feet per mile, so it can readily be seen what extensive changes are necessary to be made in that stretch to make the river carry all the water that Iron Canyon sometimes delivers.

Engineers studying the problems long ago agreed that whatever may ultimately be done for the solution of the several problems, it will all fail of giving protection to the islands of the Sacramento delta unless extensive channel enlargement and rectification be done at the confluence of Sacramento and San Joaquin rivers.

All of the drainage of the Sacramento must enter into the bay through a narrow pass. Just above Rio Vista, where the overflow from up the river coming down through the Yolo Basin reenters the Sacramento through Cache Slough, the river was formerly 2,600 feet in width. This has been reduced to about 1,800 feet by means of jetties. A few miles below this the channel is only 700 feet between banks. When a flood wave is rolling down the river it must mount higher and higher as the channel narrows, and when it meets the incoming tide, five or six feet high, forming as it were, a wall of water, it must ride on top of this tidal dam, with disastrous results to the shore embankments. It therefore becomes imperative that this constriction must be removed as preliminary to any scheme for river improvement above. This is now being accomplished as will appear herein, later.

The course of a flood in the Sacramento Valley may be stated as described in a former report of this Department, as follows:

The river enters the valley at Iron Canyon, carrying an observed maximum of more than 276,000 second-feet. The channel, of varying capacities and tortuous course, traverses the length of the valley the first sixty miles in the trough, thence occupying a ridge from which the land slopes either way to lower land on both sides. After running for sixty miles the stream is augmented by Stony Creek, from the west. Thence the channel, even in ordinary floods, begins to spill its surplus into the Colusa Basin; the water in this basin being constantly added to by overflows at intervals nearly the whole length of the river to Knight's Landing. Some is spilled along the upper reaches over the east bank and is picked up by Chico Creek, Angel Slough, and other channels, led into Butte Basin, thence into Sutter Basin and reenters the river at the lower end of the latter. When the flood wave has passed and the water level in the river lowers, Colusa Basin begins to return its waters to the river through Sycamore Slough near Knight's Landing. From Stony Creek to Feather River, a distance of 117 miles, the Sacramento has no tributaries, but sometimes, as in 1907 and again in 1909, when Butte Basin is already full, Feather River breaks over its banks 10 or 15 miles below Oroville, and the escaping water, running across the plains north of Marysville Buttes, enters Butte Basin, swelling the volume already there until the Sacramento River levees near Colusa are overtopped, engorges the river and adds to the outflow toward the west into Colusa Basin. Feather River, which also occupies high land, receives Yuba and Bear rivers on the east, overtops its banks and flows into Sutter Basin on the west, swelling the volume already received from Butte Basin.

The Sacramento having parted with its surplus in the upper reaches would now be able to keep within its banks were it not for the return of those last waters through Sutter Basin and the addition of the waters of the eastside tributaries just named.

Being swollen by these accessions the water now begins to flow out over the west bank in a broad sheet, the water running to lower land in Yolo Basin. Arriving at Sacramento city, the river is again reinforced by the American River. This stream, when gorged, flows over its banks to the north, filling American Basin, which already has received considerable quantities of water from the Sacramento River and the foothill drainage. Below Sacramento the river would, except for levees, overflow both banks all the way to Rio Vista, that to the west, running into Yolo Basin, and that on the east flowing towards Stockton until intercepted by the Mokelumne, by which stream it would be conducted into the San Joaquin. Near Rio Vista the waters that were discharged into Yolo Basin are returned to the river through Cache Slough, the quantity here entering having been largely increased by the hill drainage from the west of the basin.

Since records of stream flow have been kept the greatest floods visiting the Sacramento Valley occurred in March, 1907, and January, 1909.

Prior to those floods, one occurred in February, 1904, but at that time gauges had not been established on all of the streams, and upon those that were metered with the exception of Sacramento River at Red Bluff, the flow was far less than that registered in the two years named.

The following table, compiled from the records of stream flow is presented to show the comparison of floods, occurring in the years above named:

TABLE 3.

Comparison of the flood flow into Sacramento Valley for March, 1907, and January, 1909.

Streams	Flow at crest, cubic feet per second			Greatest daily mean flow—second-feet.		Greatest 4-day mean—second-feet	
	Mar., 1907	Jan., 1909	Maximum flow	Mar., 1907	Jan., 1909	Mar., 1907	Jan., 1909
Sacramento	204,000	205,000	254,000	187,000	137,000	152,000	129,000
Feather	187,000	137,000	187,000	187,000	137,000	135,900	115,200
Yuba	100,000	111,000	[1]125,000	100,000	111,000	75,200	79,500
Bear	25,800	29,600	29,600	25,800	25,300	16,300	17,400
American	[2]119,000	98,000	[2]125,000	105,000	98,000	83,400	77,900
Stony Creek	26,600	22,100	39,700	26,500	22,100	16,700	16,800
Cache Creek	20,300	20,800	20,800	19,200	20,100	13,400	11,900
Putah Creek	37,000	28,800	37,000	30,000	28,800	16,100	18,300
Unmetered	120,000	105,000	120,000	120,000	105,000	76,000	76,000
Total flow into valley	839,700	757,300	----------	800,500	684,300	585,000	542,000

[1]The maximum "peak" of the flood in the Yuba River in March, 1907, when the debris barriers erected by the Debris Commission were swept away, has been estimated to have been 125,000 second-feet.

[2]The flood on the American carried away the gauge and it is believed that the crest flow reached the maximum. Adding the 31,000 second-feet thus found to the recorded crest flow stated in column two of the table gives a total of 870,700 second-feet as being the probable quantity of water entering the valley on March 19, 1907.

In making investigations for the purpose of fixing a channel capacity to carry maximum floods, high water marks in the American River were pointed out by people who were present at the time of the flood in 1862, and from the data thus obtained it is estimated that American River contributed 185,000 to 200,000 second-feet of water to that memorable flood.

In column 4 of the table, the maximum flow stated for Sacramento River occurred on February 3, and that for Stony Creek, February 2, 1907.

Had all of the maxima stated in the table occurred at one time the aggregate flood would have exceeded 938,000 second-feet.

Few people realize that the Sacramento River is the fourth river of the United States in magnitude of flood flow, being larger in volume than the Missouri, Arkansas or Red rivers; larger than the Mississippi above the confluence of the Missouri and nearly equal to both the latter below their junction.

The three rivers affording a larger flood flow than the Sacramento are the Columbia, Ohio, and the Mississippi below the Ohio.

A comparison of the flood volumes of the principal rivers of the United States appears in the following table:

TABLE 4.

Comparison of flood discharge of rivers in the United States.

Stream	Maximum flood discharge, second-ft.	Drainage area, square miles	Run-off, second-feet per square mile
Missouri	546,000	527,000	1.03
Mississippi above Missouri	366,000	165,000	2.33
Ohio	1,233,000	201,700	6.11
Mississippi (Vicksburg)	1,777,000	1,100,000	1.61
Columbia	1,390,000	237,000	5.86
Sacramento	840,000	24,000	35.00

A striking feature of the above table is the large run-off per square mile of the Sacramento drainage as compared with the others, which emphasizes the rugged character of the area drained by it.

Contemplation of the enormous floods as expressed in the foregoing figures, with knowledge of the limited carrying capacity of the natural channels, leads all who are conversant with the facts to the same conclusion, viz:

That to contract the waterways with levees and at the same time to attempt to prevent inundation of the basins at the side, must be futile.

In discussions of this subject by this Department in former reports, it was said:

All along both banks of the streams, levees have been constructed in attempts to keep the water from overflowing the adjacent lands; but no extensive flood has ever yet occurred that these levees were not somewhere breached, entailing great loss to the lands and crops inundated. Millions of dollars have been spent in futile efforts at protection and other millions lost because of their failure.

The first thing that strikes the notice of even a layman in examining the river is the glaring fact that the levees are too close to the banks, almost everywhere. It is less than a thousand feet from the wharves of Sacramento city to the levee on the opposite side and thirty feet height measured on the gauge endangers them. The maximum amount of water entering the valley above Sacramento city on March 19, 1907, has been estimated at more than 600,000 second-feet. Think of carrying that amount between banks 1,000 feet apart. With the present channel capacity, it would have to move at a velocity of sixteen feet per second, or if it were possible to restrict the velocity to ten feet per second, it would require the levees to be raised about twenty feet higher, neither of which conditions could possibly be attained.

The problems of the maintenance of navigation, protection from floods and the drainage and irrigation of land have been studied by able engineers, and good, bad and indifferent solutions offered; but the first requisite is a unification of purpose and harmony of effort among the various and varied interests involved. That having been attained, methods may quickly be determined upon and carried out. But to give it the wonderful development it can and should have, all interests must unitedly strive for and accomplish restoration of navigable conditions, protection from flood disaster, and reclamation by drainage and irrigation where these improvements are required.

From the data of surveys, gauge readings and information furnished by the United States Geological Survey, and a study and observation of the Sacramento

River, it is very evident that in a general comprehensive scheme of improvement for flood conditions of the river we must open wide the mouth of the stream, make cuts to obviate the bad sharp turns below Rio Vista, then continue up the river, cutting out all bad bends. We should begin at the mouth of the river rather than from any midway or other point and pursue the work up stream. If the stream were straightened out above Rio Vista to Red Bluff then the waters would rush down and pile up in the lower reaches of the river, endangering vast tracts of reclaimed lands. Probably the most important part of a general scheme for flood control is the systematization of the location and construction of new levees and the proper replacing of the old ones. The levees are now perched upon the bank ridge so close to the water line that a few feet of erosion endangers not only the levees, but perhaps valuable crops on thousands of acres of land. There are so many diversified opinions and interests involved that it is a difficult matter to get one or several landowners to begin the work upon a proper basis when his or their neighbors entirely disregard the plan. This manifestly is wrong and some central authority should have power to compel the landowners to levee their lands in a way to protect the interests of the whole people affected by the reclamation.

This authority must have powers that command the whole levee system. Until we adopt a plan of this nature, a recurrence of the disastrous breaks caused by flood waters will continue, and relief can not be expected. For flood relief there must be sufficient cross-sectional area to carry away the highest water, and near the mouth of the river there must be provided such area way between levees that when the flood waters happen to meet the high tide the river waters may pass over the crest of the tide.

The foregoing suggestion from the Department of Engineering to provide more capacious channelway for the floods and to place the matter under state control was not a new proposition. In the report of John A. Brewster, State Surveyor General, in 1856, he described the conditions and offered a plan for flood control in the Sacramento Valley identical in its main features with the plan since adopted by the State. The report says:

The Feathers, Yubas, and Upper Sacramento bring the great body of waters from the upper country, which being concentrated at the mouth of the Feather and there finding the channel of the Sacramento unable to carry them off, overflow its banks and spread down the side of the river to Suisun Bay. I would propose to cut a canal from the Sycamore Slough down the edge of the overflowed land to the bay.

Now mark these words from that report:

A system of reclamation similar to the one proposed, or in fact any other should not be left to individuals or counties, but be general for the whole state where required and under the care of a state officer. Now is the time for a determination of the state policy in regard to this matter, and when a proper system is once adopted, all direct legislation thereupon should be in accordance with it.

In 1894 Messrs. Marsden Manson and C. E. Grunsky, consulting engineers to the Commissioner of Public Works, submitted a plan for flood control of the Sacramento River. Its essential features were as follows:

1. *Channel rectification.*—The enlargements of the natural river channels to their greatest capacity, and the straightening of crooked portions and the confinement of water to the improved channels.

2. To divert surplus water above the safe carrying capacity of the channels at selected points, and to control its diversion by means of permanent concrete weirs.

3. To convey the diverted surplus waters in by-passes, that is, between substantial levees properly placed down the trough of the basins, returning the water again to the river at proper points.

The rectification of the channels embraced the widening of the mouth of the Sacramento below the mouth of Cache Slough, and the utilization of Steamboat Slough as one of the main drains.

The by-pass in Butte Basin was to be 2,400 feet wide with the tops of the levees 3 feet above the assumed flood plane.

The Sutter Basin by-pass was designed to be 2,500 feet between levees 15 feet high, and to have a capacity to carry 70,000 second-feet.

The Colusa Basin by-pass was to be 800 feet in width, and to serve principally as a drain to carry off the drainage entering from the west side. It was intended to cut through the Knights Landing ridge and connect into the Yolo by-pass.

The by-pass down the Yolo Basin was to be 4,000 to 4,500 feet wide, with levees 15 feet high. Its capacity was to be 108,000 second-feet to Putah Creek and 130,000 second-feet below that point.

The easements or weirs were to be placed as follows:

The Butte Basin weir 4,000 feet long, 2 miles above Butte City.

Colusa Basin weir, 750 feet long, 4 miles below Jacinto.

Sutter Basin, one in the head of Butte Slough, another at Tisdale break, combined length 3,700 feet.

Yolo Basin, two weirs having aggregate length of 6,500 feet, below the mouth of Feather River, and a third, 1,200 feet in length, 7 miles below Sacramento City.

The crests of all of these weirs were to be at the general height of the river bank and at about 3 feet below the assumed flood plane.

The Commissioner of Public Works constructed three of the weirs recommended, to wit: Butte Slough, Tisdale and Elkhorn, 10 miles below the mouth of Feather River. These weirs discharged directly into the basins without levees or training walls to conduct the water through the basins. None of them were of the dimensions recommended in the report. The first named, Butte Slough weir, washed out before it was completed and has never been replaced. The other two are still intact and operate at each flood. The maximum discharge provided for in this plan was 200,000 second-feet below Cache Slough.

Before the system of stream measurement was installed giving accurate information as to flood volumes, eminent engineers differed in opinion as to the proper methods for handling the problems.

In 1880, Wm. Ham. Hall, State Engineer, associated with a board of consulting engineers consisting of Gen. George S. Alexander and

Col. Geo. H. Mendell, Corps of Engineers, United States Army, devised a plan to confine the river to a single channel by high and strong levees. If the flood flow were held in one channel, the great volume would scour the river bed deeper and create a capacious channel.

Temporary by-passes were to be provided to carry off surplus water until the river had increased its channel capacity to carry all floods.

In 1904 a commission composed of Major T. G. Dabney, Chief Engineer of the Yazoo Mississippi Delta Levee District; Major Henry B. Richardson, member of the United States Mississippi River Commission; Major H. M. Chittenden, Engineer Corps, U. S. Army, and M. A. Nurse, Chief Engineer for the Commissioner of Public Works of California, made a study of the flood control problem on the Sacramento and presented a plan for its solution.

The plan recommended by this commission, frequently referred to as the Dabney Commission, follows the general lines suggested by General Alexander and his associates in 1880. Its main features as stated in the report are as follows:

(*a*) To confine the flood waters to the channels of the various streams by means of levees, so as to prevent destructive inundations of the fertile lands.

(*b*) To correct the alignment of the river by cut-offs where necessary, and to increase its channel capacity by mechanical means wherever current action fails to accomplish this purpose.

(*c*) To collect the hill drainage, which now loses itself in the basins, in intercepting canals and convey it into the river at selected points.

(*d*) To provide escapeways over the levees for surplus flood waters during the period of channel development, and to provide for the disposal of this water in connection with the hill drainage.

(*e*) To provide for the relief of the basins from accumulation of rain and seepage water by means of pumps wherever gravity drainage is not practicable.

The flood discharge to be taken care of was estimated to amount to 250,000 second-feet at the mouth of the river. This estimate was based upon careful analyses of all data available at that time. The cost of the proposed works was estimated at $23,776,000.

Like all other plans that had been offered for the reclamation of the great Sacramento valley from the devastating floods that periodically visits it the elaborate report of the Dabney Commission was "received and placed on file" without action taken thereon. And so it has been from the very dawn of the state's history—state engineers, federal officers, commissions and boards of public works have time and again urged the measures advocated by Brewster, but not until more than half a century had elapsed did the legislature declare a settled policy for the state.

Sixty years of abortive attempts to reclaim the overflow lands by individual action; of periodical floods causing the loss of crops and destruction of property worth millions of dollars; of growing injury

to navigation—sixty years of investigation, agitation and effort to unite and harmonize varied interests, and twenty years of study and research by the agents of the Government finally crystallized into a comprehensive plan—a gigantic project for the control of floods, improvement of navigation and reclamation of flooded lands.

This plan is presented in a report made to the Government by the Debris Commission, under the title, "Reports on the Control of Floods in the River Systems of the Sacramento Valley and the adjacent San Joaquin Valley, California," dated August 10, 1910. It was transmitted to the House of Representatives by the Secretary of War, June 27, 1911, and two days later referred to the Committee on Rivers and Harbors, and printed as House Document No. 81, sixty-second congress, first session.

FLOOD CONTROL.

This report and the plan proposed by it was made in pursuance of the provisions of an act of congress approved March 1, 1893, known as the "Caminetti Act," creating the California Debris Commission which act prescribes the duties of the commission to be:

1. To regulate hydraulic mining so as to permit the resumption of that industry so far as is compatible with the protection and restoration of the navigability of the Sacramento, Feather and San Joaquin rivers, and the prevention of damage from overflow.
2. To improve the navigability of all the rivers of this system, deepen their channels and protect their banks, with a view of restoring as near as practicable and the necessities of commerce and navigation demand the navigation of said rivers to the conditions existing in 1860.
3. To afford relief in flood time and to provide sufficient water to maintain scouring force in summer season.

The first object stated in the Caminetti act was quickly accomplished after the Debris Commission was formed.

The second object was made the subject of several years investigation and study, resulting in plans for partially obtaining the desired end, which will be more fully described under the head of "Debris Control." In a special report dated June 30, 1907, the commission submitted plans for the continuance of the control of debris in the tributaries of the Sacramento River.

The third object enjoined by the act creating the Debris Commission: "To afford relief in flood time and provide sufficient water to maintain scouring force in summer season," was the subject of the exhaustive report above referred to as appearing in House Document No. 81.

This report was made to the Chief of Engineers, United States Army, and he, in transmitting it to the Secretary of War, said:

Recognizing that the interests of navigation, debris control and flood control are inseparably connected, the commission has considered these problems as one general project, thus utilizing for the common good to the fullest extent practicable the works for any one of the three projects.

A preliminary report in 1907 had recommended enlarging and straightening the lower reaches of the Sacramento as a necessary part of any scheme for flood control, and asked for $800,000 for beginning the work. The report was made after the California legislature had adjourned, but promptly upon its reassembling by an act approved March 1, 1909, it appropriated one half of the amount asked for.

Congress in the River and Harbor Act, approved June 25, 1910, appropriated a like amount, making $800,000 available for the purpose stated. The state's appropriation was placed in the treasury of the United States to be expended by the national authority for the purpose specified.

Referring back to the plan for complete control of floods in the Sacramento, proposed in the report of the Debris Commission, referred to as House Document No. 81, (62d congress). After going extensively into the history of floods and flood conditions, quoting all available data, and discussing former reports and plans, particularly the Dabney plan of confining the floods to one channel, the report says:

> The principal objections to this project (Dabney plan) are its incompleteness and owing to lack of flood-discharge data, its inadequateness. The principals upon which it is based, however, are sound. The project proposed by the commission differs from that project principally in providing for the complete control of a much larger flood discharge.
>
> It seems practicable to control the floods in this river and its tributaries in such a manner as to secure the desired results without the objectionable features of injury to Suisun Bay; injury to navigation in Sacramento River from Cache Slough to Colusa; indefinite period of construction, and excessive cost.

With regard to the difference in magnitude of flood flow provided for in the two projects it points out that the former plan was for 250,000 second-feet at the mouth of the river, while the flood of 1907 had furnished 600,000 second-feet and continues:

> That project provided for the moving of about 320,000,000 cubic yards of material, of which 214 millions were to be removed by the river (scour) and carried to tidal waters. A modification of the project to meet the present known maximum flood discharge will involve the moving of more than two and one half times the above amount. If the same assumption is made with reference to scour by the river, then about 545,000,000 cubic yards will be carried to tidal waters. This amount of material cannot be carried into Suisun Bay without injury to that body of water, resulting in injury to navigation on both the Sacramento and San Joaquin rivers and the reclaimed areas along that bay.

The new plan proposed by the Debris Commission was to consist of the following:

1. Increasing the carrying capacity of the river above the Moulton Break to 250,000 second-feet by moving the levees farther apart and making them higher.

2. Constructing a weir at Moulton's break, 13 miles above Colusa, and connecting it by a permanent by-pass through Butte and Sutter basins with the Sacramento River at the confluence of Feather River.

The Moulton weir to have a capacity to pass 185,000 second-feet, and the by-pass to carry 220,000 second-feet. This would reduce the flow in the main river below the Moulton weir to 65,000 second-feet.

3. Reconstructing the present Tisdale weir so as to pass 35,000 second-feet and convey it in a by-pass to the Sutter Basin by-pass. There will then remain 30,000 second-feet in the river below Tisdale weir.

4. Confining the flood waters of the main river to its channel between escape weirs, and also confining the waters of Feather River and all other tributary streams.

4*a*. The ,improvements proposed for the Sacramento River between Moulton Weir and Feather River contemplate four cutoffs, viz: Race-track Bend, Ministerial Bend, Collins Eddy, above Knights Landing, and one cut eliminating Grays and Woods bends, below. No other cutoffs are contemplated on the main river or any tributaries, but improvement is proposed of Steamboat Slough above Cache Slough, by moving back and raising its levees.

5. Constructing a weir opposite the mouth of Feather River to carry all flood waters in excess of the capacity of the river below. It is estimated that the river below the junction of Feather River may carry 50,000 second-feet, and that the weir (since named Fremont weir) will be required to pass 400,000 second-feet, to be conveyed in a by-pass through Yolo Basin to Cache Slough. This by-pass will receive accessions of flood waters from Colusa Basin, Cache and Putah creeks and the drainage from the Coast Range hills and West side plains. The by-pass channel to be enlarged as it progresses to accommodate these accessions.

6. Constructing a drainage canal from Colusa Basin through Knight's Landing ridge to connect with Yolo by-pass. This canal to have a capacity of 10,000 second-feet.

7. Constructing a weir at Bryte's Bend, two miles above the mouth of American River, and connecting it by a by-pass channel with Yolo by-pass. This weir to divert 70,000 second-feet, leaving 100,000 second-feet of the combined waters of American and Sacramento rivers to be carried by the main river to the junction of the Yolo by-pass at the mouth of Cache Slough.

8. Improving the river below the American so as to carry 100,000 second-feet.

9. Dredging the river below Cache Slough, widening and deepening the channel to flood channel section to carry 600,000 second-feet. This work includes a cutoff across Horseshoe Bend.

10. Collecting drainage from hills and adjacent plains in intercepting canals and conveying it to the river or by-pass channels at convenient points.

11. Providing for the drainage of the basins by culverts and gates and installing pumping plants at various points.

Item (6) above, Colusa Basin Drainage Canal is made necessary by reason of the construction of the levees below Tisdale weir which would close Sycamore Slough at Knight's Landing, and which is the natural drainage channel from Colusa Basin. The Colusa Basin Canal has since become known as "Knight's Landing Ridge Cut."

The great flood of 1907, which is considered the largest that has occurred since the occupation of the country by Americans, with the exception of that in 1862, was exhaustively analyzed in a paper presented to the American Society of Civil Engineers by Messrs. W. B. Clapp, E. C. Murphy and W. F. Martin in 1908.*

The estimates of flood discharge presented in this paper were largely used as a basis for the estimates by the Commission of the requisite channel capacities, concerning which, after quoting tables comparing different floods, the report says:

It is thought that the estimates of Messrs. Clapp, Murphy and Martin should be followed very closely in determining the necessary channel widths, and their maximum is assumed, with certain allowances for flattening of the flood wave in passing down the improved channels.

It is doubtful if the flood in the American was a maximum in 1907 and it is not considered safe to estimate its maximum flood discharge at less than 120,000 second-feet.

Considering the above discharge data and the estimated maximum flood discharge of Messrs. Clapp, Murphy and Martin, it is considered that provision should be made for the following discharges:

	Second-feet
Sacramento River below Stony Creek	260,000
Stony Creek	30,000
Sacramento River at Moulton weir	250,000
In river to Tisdale weir	65,000
In river from Tisdale weir to Feather River	30,000
Tisdale by-pass	35,000
Sutter-Butte by-pass	185,000 to 220,000
Feather River above Marysville	150,000
Yuba River	110,000
Bear River	30,000
Feather River below Marysville	240,000
*Yolo by-pass at spill-way	400,000
Yolo by-pass below Colusa Basin Canal	410,000
Yolo by-pass below Cache Creek	425,000
Yolo by-pass below American by-pass	490,000
Yolo by-pass below Putah Creek	510,000
From Feather River to American River	50,000
From American River to Cache Slough	100,000
Below Cache Slough	600,000
American River	120,000
Colusa Basin Canal	10,000
Cache Creek	20,000
Putah Creek	25,000
†Sacramento by-pass	70,000

*Fremont weir.
†Bryte's by-pass.

The above discharges are large and much larger than many may consider it advisable to provide for. The floods considered, however, were of long duration and but little reduction can be allowed for the flattening of the flood wave under such

*Volume LXI, Transactions American Society of Civil Engineers, pp. 281-330.

conditions. In the projects that have heretofore been seriously considered, the estimated flood discharges of the main river and of most of its tributaries have been abnormally low, and the possibility of even those low discharges being maintained for some days was not considered probable. The floods of 1907 and 1909 have proved conclusively that a flood in this river may continue for several days at almost the point of maximum discharge. Failure to provide for a discharge such as is shown by these floods of 1907 and 1909 would leave open the way for damage by the occurrence of a similar flood.

The cost of the proposed project the Commission estimated would be $33,800,000 of which sum $800,000 had already been provided by Federal and State appropriations.

The Commission expressed its conclusions upon the plan proposed as follows:

The project here submitted differs much from the commonly accepted solution, but this commission is satisfied that it more nearly meets the requirements of the case than any heretofore considered. In a consideration of this project attention is invited to its small estimated cost and short time of completition; also to the fact that the floods are controlled immediately and completely upon its completion.

The results to the State of California in permitting reclamation and preventing damage to reclaimed lands are great, but the United States also gains in keeping the present channels uninjured. It is the opinion of the commission that both should therefore share in the construction of the works under this project, the United States to the extent of 33⅓ per cent. It is also the opinion of the commission that the State of California will benefit to such an extent by the control of the floods of the river that upon the completion of this project it should take over and maintain all flood-control works, the United States to provide only for the maintenance of the navigable channels. This seems an equitable distribution both of the first cost and the maintenance.

It is therefore recommended:

First—That the United States begin at once the work for the control of the floods of the Sacramento River in accordance with the above project and provide for its early completion.

Second—That the United States contribute one third of the cost of work and the State of California contribute the remaining two thirds.

Third—That upon its completion the United States turn over to the State of California for maintenance all flood-control works.

In alloting two thirds of the cost of the work to the state, the idea in mind was that it would be divided equally between public appropriations and assessments or contributions collected from the lands benefited by their permanent reclamation. The report was dated August 10, 1910. It was transmitted to the Secretary of War by the Chief of Engineers, June 24, 1911, and by the secretary to the House of Representatives on June 27th and referred June 29, 1911, to the Committee on Rivers and Harbors and ordered to be printed with illustrations.

Soon after the submission to congress of the Debris Commission's report the Governor of California called an extra session of the legislature, and among the matters commended for consideration was the Commission's proposed flood control project.

By an act approved December 24, 1911,* the report of the Debris Commission was approved with such modifications and amendments as might be found advisable as a plan for controlling the flood waters, improving navigation and reclaiming the overflow lands.

Thus, for the first time in the long history of this matter did the State of California adopt a policy and commit itself to a definite method of procedure. In addition to approving the report of the Commission the act created a State Reclamation Board to carry the project into effect so far as concerned the state's share.

This board was given jurisdiction over any plan of reclamation undertaken on the Sacramento and Feather rivers in order that such plans should not conflict with the flood control project as approved or to be modified and amended by the board. The State Engineer was directed to procure data and make such surveys as might be required to enable the Reclamation Board to amend or modify the proposed plans. The sum of $10,000 was appropriated to pay the expenses of the surveys.

The Reclamation Board consisted of three members and the Governor appointed V. S. McClatchy of Sacramento, W. T. Ellis, Jr., of Marysville, and Peter Cook of Rio Vista, to constitute the board. The adoption of a comprehensive scheme for flood control and reclamation under the direction of a state body with large powers came none too soon. Ever since reclamation commenced in 1852 any land owner in the overflow region was permitted to "fight the common enemy" in his own way, even though his way meant devastation to his less vigilant or weaker neighbor. Efforts to reclaim the valuable lowlands continued—levees were built, farther and farther into the basins. The investigations made for the board discovered that already such levees extended more than a mile into one of the by-passes that is a vital part of the whole enterprise. Other projects were under way, encroaching upon the waterways contemplated by the Debris Commission's plan. Unfortunately, the law creating the Reclamation Board gave it jurisdiction over reclamation plans "hereafter adopted," so that the plans already inaugurated could not be interfered with nor changed excepting so far as their promoters could be influenced by "moral suasion." This latter was sometimes accomplished. The board found one private enterprise preparing to carry out plans that would completely block an important proposed by-pass. Through the efforts of the board that and other similar obstructive projects were modified to conform to the general flood control plan, or abandoned.

The adoption of a settled policy of state control over reclamation and flood control in a way that gave promise of absolute protection greatly stimulated individual effort along those lines. Indeed, so actively did private interests enter upon reclamation and so diligently did they

*Chapter 25, Statutes, Extra Session, 1911.

prosecute extensive plans, approved by the Reclamation Board, so as not only to avoid encroaching upon the Debris Commission plan, but on the contrary to form a part of those proposed works, it was soon found that a great deal of the public work planned by the commission was being done by private enterprise, making it possible to eliminate much of the cost estimated in the commission's report of 1910. Thereupon the Committee on Rivers and Harbors of the House of Representatives on December 2, 1912, requested the Board of Engineers for Rivers and Harbors to review the report embodied in H. R. Document No. 81, 62d Congress, and to report subsequent information and conclusions thereon.

In compliance with that request the Debris Commission reported February 8, 1913, giving account of the tremendous development above mentioned and the great progress made toward accomplishing the end sought in its former report. The commission estimated that in view of what had been accomplished and the work already planned by private enterprise, the joint governmental costs to complete the works for the control of debris and floods and improvement of navigation according to the plans contemplated in its 1910 report would be $11,717,008, not including the $800,000 appropriated jointly for work at the mouth of the river, and not including costs for rights of way.

The Commission recommended that one half of the estimate, or $5,858,504 be paid by the United States and the other half by the state and that all rights of way be furnished without cost to the United States. It will be seen from the above stated figures that the National Government's share of the cost has been reduced nearly one half. The land owners, however, will not be so fortunate, since they are expected to procure the rights of way, and the price charged for the land to be taken will far exceed the prices considered in the original estimate.

Mention was made in a former paragraph of the appropriation of $400,000 by the legislature and a like amount by congress to begin the work of widening the mouth of Sacramento River as recommended by the preliminary report of the Debris Commission in 1907 and included in the flood control plan of the Commission's report of 1910.

With the $800,000 fund in the treasury of the United States the Government was ready to begin the preliminaries for widening the mouth of the river, and to that end a contract was let February 28, 1912, for the construction of two 20-inch suction dredges.

The contract price for these huge machines was $353,600. Contracts were let in November for 7,400 lineal feet of 20 and 21-inch discharge pipe, and in January, 1913, for pontoons to carry the pipes; for a dredge-tender driven by gas engines, and other equipment.

Foreseeing that the completion of the dredges and their operation later, would exhaust the funds provided, the state legislature in 1913

Plate XX—A. Dredge "San Joaquin," Widening Mouth of Sacramento River.

B. Scene on Sacramento River. Natural Bank Protection.

appropriated *$200,000 to continue the work, anticipating that congress would appropriate a like amount.

The dredges with full equipment and accessories, including a mooring basin, wharf and warehouse at Rio Vista, were completed and the two dredges named "Sacramento" and "San Joaquin" were placed in commission in the summer of 1913 and were then ready to begin the work of enlarging the lower reaches of the river.

Removing the constriction below Cache Slough and enlarging the stream from a capacity of 165,000 second-feet to a size capable of passing the accumulated floods from above, now known to amount to 600,000 second-feet, has received the popular designation of "uncorking the bottle."

The surveys and investigations made by the Department of Engineering in behalf of the State Reclamation Board had shown that complete control of floods in the Sacramento could not be accomplished without at the same time controlling the floods of the San Joaquin Valley.

SAN JOAQUIN VALLEY.

Three quarters of a million acres of land are subject to overflow from the flood waters of the San Joaquin and its tributaries, which lands are equally as fertile as those of the Sacramento, and equally entitled to any benefits that the other might receive from governmental protection.

Recognizing the necessity of effecting flood control, reclamation and improvement of navigation upon both stream systems as a whole, the legislature in 1913 passed an act extending the scheme to include the San Joaquin, and enlarging the Reclamation Board to administer it. The essential features of this act (Chapter 170, Statutes 1913), are epitomized as follows:

The district is designated "Sacramento and San Joaquin Drainage District."

The boundaries extend from near Chico Landing on the Sacramento, enclosing the flooded area on both sides of the river, including Feather River a short distance below Oroville; including Marysville, Colusa, Sacramento, and to the mouth of Sacramento River, and thence covering the entire San Joaquin Delta region excepting in the immediate vicinity of Stockton, thence up the San Joaquin to a point about eight miles above the junction of Fresno Slough.

The State Engineer is directed to gather data, make surveys and investigations for the formulation of plans for the improvement of navigation and the reclamation of lands subject to inundation in both valleys.

The management and control of the district is vested in the Reclamation Board which is increased to seven members, at least three of whom

*Chapter 452, Statutes 1913, approved June 7, 1913.

must be residents or land owners in that portion of the district lying in San Joaquin Valley.

Any plan of reclamation within the territory subject to inundation must be approved by the Reclamation Board, and unless so approved is void and works undertaken without the board's approval are declared to be a public nuisance and may be prosecuted or abated by the board by suit in the courts.

The intent of the act is best described in section 7 of the act itself, which is here quoted:

The State of California and the people thereof are hereby declared to have a primary and supreme interest in having erected, maintained and protected on the banks of the Sacramento and San Joaquin rivers and their tributaries and the by-passes and overflow channels mentioned herein, good and sufficient levees and embankments or other works of reclamation, adequately protecting the lands overflowed by said streams and confining the waters of said rivers, tributaries, by-passes and overflow channels within their respective channels, and it shall be the duty of the reclamation board at all times to enforce on behalf of the State of California and the people thereof the erection, maintenance and protection of such levees, embankments and channel rectification as will, in their judgment, best serve the interests of the State of California. The purposes and objects of this act are to carry into effect the plans of the California Debris Commission for the control of the flood waters of the Sacramento and San Joaquin rivers and their tributaries, and to vest in said reclamation board control and jurisdiction over said plans and such other plans as may be adopted by said board, excepting such portions of said plans as relate to channel excavation, enlargement, rectification and control in the Sacramento River and the construction of weirs; it being the intent of this act that all work and control in the said stream and the construction of weirs shall remain with the United States and the State of California, concurrently, but this exception does not apply to the San Joaquin River and its tributaries.

This act and every part thereof shall be liberally construed to promote its objects and to carry out its intents and purposes.

The possibility of adapting the by-pass channels to navigation and their protection against being obstructed by fixed bridges or other structures is safeguarded by section 10 of the act, as follows:

The reclamation board shall require the owners of any railroad, electric railroad, wire line, wagon road or other structure crossing any of these by-passes or overflow channels herein provided for, to provide and maintain one or more suitable draws or other appliances within any such by-passes or overflow channels to permit the passage of water craft, dredgers or other machines used in the construction of reclamation works and to open said draws or appliances upon reasonable notice given by any person desiring to pass the same. Said draws or appliances shall be located at such points as shall be designated by said board. A failure of the owner of any of said structures to comply with this section shall render such owner liable to any person for the damages caused to such person by such failure.

The board is empowered to acquire by purchase, condemnation or otherwise, lands, rights of way, easements, property or materials, requisite for the purposes of the project;

To levy assessments upon the lands in the district to provide funds;

To examine reclamation or drainage districts which have issued bonds and to certify as to the sufficiency of the security for such bonds.

The sum of $100,000 was appropriated, with the proviso that $50,000 should be returned to the State Treasury out of the first moneys collected for assessments upon the lands of the district; $20,000 of the appropriation was directed to be allotted to the State Engineer to pay the expenses of the surveys and investigations enjoined upon him.

The Sacramento and San Joaquin Drainage District lies in fourteen counties. The approximate area in each is exhibited in the following table:

*TABLE 5.

Approximate area of district.

County, Sacramento valley	Area, acres	County, San Joaquin valley	Area, acres
Butte	121,677	San Joaquin	256,960
Glenn	69,760	Contra Costa	50,240
Colusa	178,880	Stanislaus	36,956
Yuba	57,600	Merced	202,880
Sutter	222,080	Madera	55,040
Yolo	173,280	Fresno	67,040
Solano	55,520		
Sacramento	178,640	Total, San Joaquin Valley	669,116
		Total, Sacramento Valley	1,057,437
Total, Sacramento valley	1,057,437		
		Total in district	1,726,553

*The figures in the table are taken from the report of the Reclamation Board, April, 1914.

The enlarged Reclamation Board was completed by the appointment of A. G. Folger of Sacramento, G. A. Atherton and Louis H. Frankenheimer of Stockton, and M. C. Zumwalt of Tulare. The members of the former board, V. S. McClatchy of Sacramento, W. T. Ellis of Marysville, and Peter Cook of Rio Vista, were continued in office under the terms of the act.

The board organized by electing Mr. McClatchy president and Mr. Ellis as secretary. Owing to the immense amount of office work developing it was found necessary to have an executive representative of the board present at all times and Mr. W. H. Hogue was appointed executive secretary.

Mr. E. A. Bailey, who had been detailed from the Department of Engineering to conduct the surveys for the old board, was assigned to the charge of surveys and investigations for the new board.

The surveys for working out the details of the project and the proper location and dimensions were vigorously prosecuted by a large force of engineering parties. At the same time a sufficient office force was maintained to keep the data well worked up and to study the relations between flood control, reclamation and navigation as revealed by the investigations made in the field.

The position for several weirs and by-pass levees were determined upon and specifications prescribed fixing their character and dimen-

sions, and only those levees built by private enterprise which conformed to the specifications have been approved by the Reclamation Board.

As located, the levees required to complete the project as outlined in the Debris Commission's report and amended and modified by the Reclamation Board aggregate 690.42 miles in length, of which 503.85 miles are levees to confine the rivers to their channels and 186.57 miles are levees forming the by-passes. They are segregated as follows:

TABLE 6.

Levees required for flood control. Sacramento Valley.

Stream	Length of channel, miles	Length of levees miles	
Sacramento	200.7	371.05	
Feather	39.7	78.10	
Yuba	*7	15.90	
Bear	*10	27.60	
American	35	11.20	
			503.85 miles
Butte by-pass	11.5	24	
Butte Slough by-pass	6	6.8	
Tisdale by-pass	4.2	8.45	
Sutter by-pass	31.15	59.29	
Yolo	42.50	84.43	
Sacramento	1.8	3.60	
			186.57 miles
Total	389.55		690.42 miles

*Approximate lengths.

Since the organization of the great reclamation and drainage district the activities of private enterprise in building reclamation works under the direction of the State Reclamation Board has progressed so rapidly that in April, 1914, the board reported that it had approved the construction or plans for the construction of 288.44 miles of the levees, constituting 42 per cent of the whole mileage required. That is to say, nearly one half of that portion allotted to the land owners is already practically accomplished.

Of the part assigned to the national and federal governments, i.e. enlarging and rectifying the river channel, and constructing the weirs at the heads of the by-passes, relatively little has been done. The location and dimensions of some weirs have been determined, but details of design have not yet been worked out.

For enlarging the river channel, as related elsewhere herein, two large dredges have been procured with which to execute it.

The work of excavating at the mouth of the Sacramento River was begun a short distance above Collinsville, by the dredges Sacramento and San Joaquin in August, 1913. Each machine is operated by a crew of about 40 men. Up to the close of the fiscal year ending June 30, 1914, there had been excavated from the channel of the river

3,373,044 cubic yards of material at a total cost of $168,036.47, or an average of 4.981 cents a cubic yard.

At this time there was a little more than $50,000 remaining of the original fund of $800,000. Congress failed to specify anything for the continuance of this work in the rivers and harbors appropriation bill, and it was feared that the dredges would have to be laid up, as the appropriation made by the state was contingent upon congress also making an appropriation. Fortunately, the Board of Engineers for Rivers and Harbors was able to allot $60,000 for the purpose, which, with a like amount from the state's $200,000 appropriation of 1913 makes a fund of $120,000, which will be sufficient to keep the dredges in operation until the next congress has an opportunity to make an appropriation for the continuance of this important work.

The work accomplished by the dredges as above related was about equally divided between the west and east sides of the river. That deposited in the west of the channel was used for filling low lands or placed out of reach of floods. Of 1,549,996 cubic yards removed by the dredge Sacramento most of it was used in building a levee along the new alignment on Sherman Island.

For more detailed account of the operations of the dredges the reader is referred to the report of the Debris Commission at the close of this chapter.

It has been stated that the San Joaquin arm of the great drainage district terminates in the San Joaquin River a few miles above the confluence of Fresno Slough. Upon examining a map of San Joaquin Valley it will be observed that the river enters the valley on the east side about midway of its length and runs directly across the valley to its junction with Fresno Slough, and turning sharply to the northwest runs along the trough of the valley to the head of Suisun Bay. From the San Joaquin River the valley extends southeasterly more than 150 miles to the foot of the encircling mountains.

About 40 miles from the bend in the San Joaquin River the valley is crossed by a ridge some 60 feet higher than the floor of the valley at the river, and 37 feet higher than the land twenty miles farther up the valley. This ridge was formed by the meeting of two "delta fans" made by the deposit of alluvial soil brought down from the mountains—on the east by Kings River, and by Los Gatos Creek on the west.

The presence of the ridge divides the valley, creating a basin to the southwest, the extreme bottom of which is the bed of Tulare Lake. This lake was formerly of considerable size, covering more than 800 square miles. When full and flowing over the ridge, the escaping water found its way to the San Joaquin River through Fresno Slough.

Kern River enters the valley at the extreme southeast corner, and its flood waters find their way to Tulare Lake. The lake is also fed by

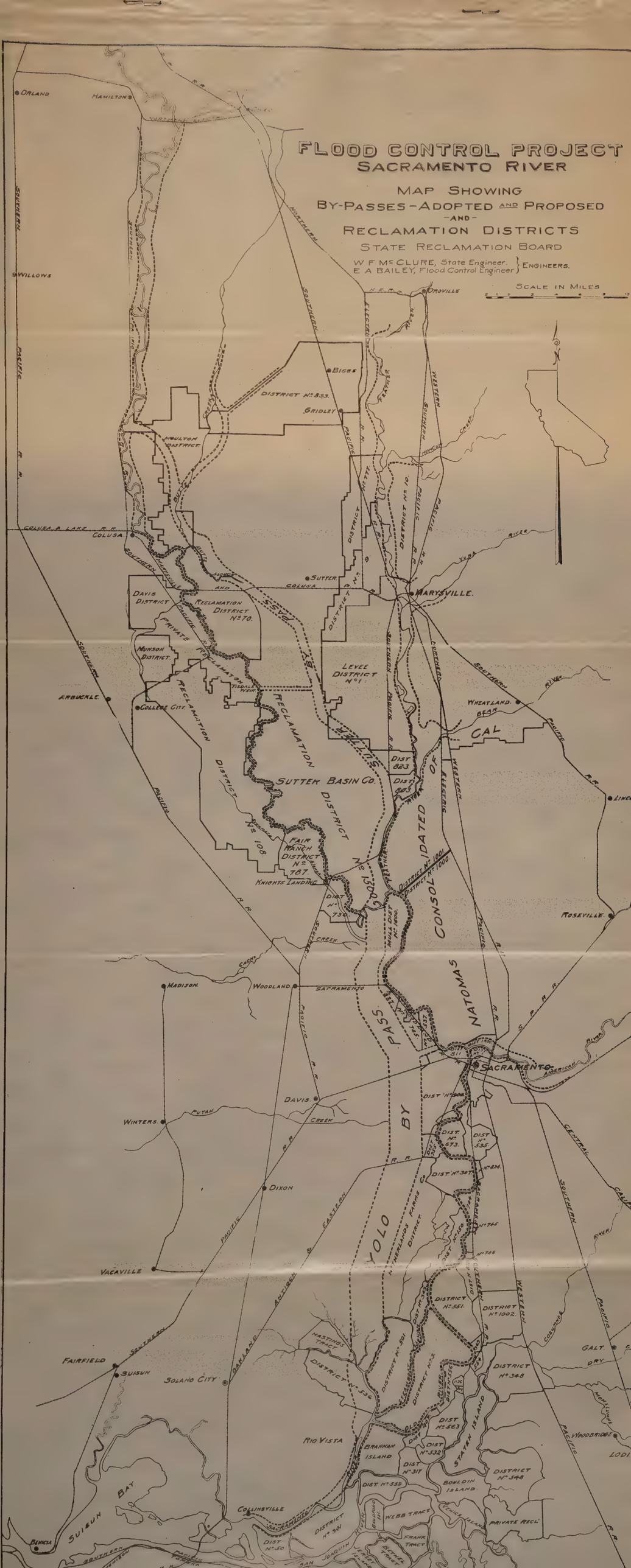
Kaweah and Tule rivers from the east and Kings River from the north. Extending along both sides of Fresno Slough to Tulare Lake, encircling the lake and extending thence on both sides of Buena Vista Slough (the overflow channel of Kern River), to and enclosing Buena Vista and Kern lakes, which are catch basins for Kern River, is a large body of overflow land ceded by the United States under the Swamp Land Act because of its being subject to periodical flooding. Extending upward along all of the streams reaching this body of swamp land are arms of the same character of land flooded by the waters of these streams.

From the mouth of Fresno Slough to the head of the valley the area of swamp and overflow land just described is about 900,000 acres, including approximately half a million acres originally covered by the waters of Tulare Lake. These lands were all covered with water at the time the United States extended its system of land surveys over the valley in the early fifties, which fact caused their segregation to the state as swamp and overflow lands. In addition to the 900,000 acres above mentioned there are about 350,000 acres in the delta regions of Kern, Tule, Kaweah, and Kings River not so segregated, but which are subject to destructive floods whenever the respective streams are swollen to flood dimensions and their enclosing dikes give way. The water escaping from the channels and flowing over the deltas are gathered together again, adding to the natural flow of the streams and all uniting to spread the flooded area on the valley floor.

It appears from the foregoing that about one and a quarter million acres of land in the San Joaquin Valley outside of the Sacramento and San Joaquin Drainage District, are subject to inundation and devastating floods.

A large part of these lands is "reclaimed" more or less completely, but as in the district, those most secure from danger owe their immunity largely to the weakness of their neighbors' defenses, though it is probable that the success of the levees in protecting the enclosed land is principally due to the fact that no excessively great floods have visited this region since reclamation works were introduced. The last flood of sufficient magnitude to fill Tulare Lake to overflowing occurred in 1867. It is quite certain that neither of the so-called floods of 1879, 1884, 1904, 1907, or 1909 was nearly so large, and there is good reason to believe that floods occurred in 1833, some time in the '40s, and in 1862, that far surpassed the extent of that in 1867 mentioned above as having filled the lake the last time.

The absence of any abnormal flood flow since 1867 and the diversion for irrigation of all of the summer flow which formerly counterbalanced the evaporation from the lake caused the latter to gradually dry away, until 1897 when it entirely disappeared. As the water


FLOOD CONTROL PROJECT
SACRAMENTO RIVER
MAP SHOWING
BY-PASSES - ADOPTED AND PROPOSED
- AND -
RECLAMATION DISTRICTS
STATE RECLAMATION BOARD
W. F. McCLURE, State Engineer.
E. A. BAILEY, Flood Control Engineer.
ENGINEERS.
SCALE IN MILES
ORLAND
HAMILTON
WILLOWS
OROVILLE
BIGGS
GRIDLEY
DISTRICT No. 833.
HAMILTON DISTRICT.
COLUSA
SUTTER
MARYSVILLE.
DAVIS DISTRICT
RECLAMATION DISTRICT No. 70.
MUNSON DISTRICT.
LEVEE DISTRICT No. 1.
ARBUCKLE
COLLEGE CITY.
WHEATLAND.
SUTTER BASIN CO.
RECLAMATION DISTRICT No. 108
FAIR RANCH DISTRICT No. 787.
KNIGHTS LANDING
CONSOLIDATED DISTRICT No. 1001
DISTRICT No. 1000
ROSEVILLE.
MADISON.
WOODLAND
PASS
BY
NATOMAS
SACRAMENTO
DAVIS.
WINTERS.
DIXON
YOLO
VACAVILLE
FAIRFIELD
SUISUN
SOLANO CITY
RIO VISTA
BRANNAN ISLAND
STATEN ISLAND
BOULDIN ISLAND
WEBB TRACT
FRANK TRACT
GLEESER TRACT
PRIVATE RECL.
COLLINSVILLE
SUISUN BAY
BENICIA
GALT
WOODBRIDGE
LODI
DISTRICT No. 551.
DISTRICT No. 1002.
DISTRICT No. 348
DISTRICT No. 556
DISTRICT No. 563
DISTRICT No. 548
DISTRICT No. 341
DISTRICT No. 317
DISTRICT No. 535
DISTRICT No. 673.
DISTRICT No. 744
DISTRICT No. 745
DISTRICT No. 746
DISTRICT No. 50
DISTRICT No. 341
DISTRICT No. 823
DISTRICT No. 1002
DISTRICT No. 1003
DISTRICT No. 1001
DISTRICT No. 1000
DISTRICT No. 1500

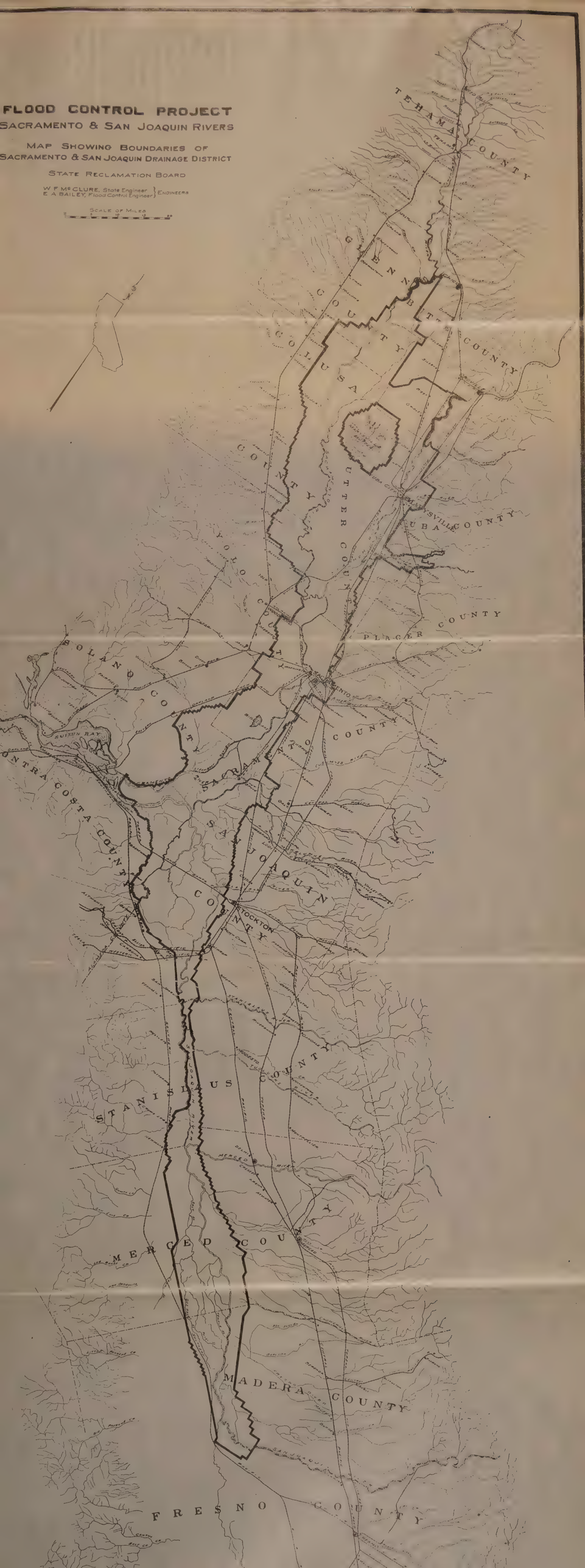
FLOOD CONTROL PROJECT
SACRAMENTO & SAN JOAQUIN RIVERS

MAP SHOWING BOUNDARIES OF
SACRAMENTO & SAN JOAQUIN DRAINAGE DISTRICT

STATE RECLAMATION BOARD

W. F. McCLURE, State Engineer
E. A. BAILEY, Flood Control Engineer
} ENGINEERS

SCALE OF MILES



receded, settlers followed it, building levees to prevent its slight rise from winter rains from flooding their lands.

The levees constructed were slight structures only a few feet high, but were considered sufficient since the people optimistically believed the lake will never come back, therefore their puny levees were all-sufficient. But subsequent events proved that their optimism was not justified, as the following recital concerning the fluctuations of Tulare Lake, from the record of the Department of Engineering will show:

During the fifties and after filling to overflowing in 1862, the area of the lake remained nearly stationary for several years and then gradually diminished. In 1880 the Government caused it to be surveyed when it was found to have an area of about 400 square miles. The elevation of the water surface at this time was about 193 feet above sea level, being then about fourteen feet deep. Its area continued to shrink and in 1896 nearly the whole lake bed was dry. Large and numerous canals had been constructed diverting all but the flood waters from all of the streams. Upon the lake bottom itself canals were built diverting the waters out of the channels and distributing them over the uncovered lands outside of the remnant pond of the lake. Water from Kings River was taken by ditches running around both sides.[1]

By 1896 nearly the whole lake bed was uncovered and under cultivation and the next year entirely so, the county surveyor that year completing the surveys for the sale by the state of every acre formerly covered by the lake. For two years following successful farming was conducted, immense crops of wheat and barley being produced, yielding as much as seventy bushels to the acre.

The winter of 1900-01 was disastrous. Many farmers were financially ruined by the waters of Kings River filling the basin enclosed by the reclamation levees, breaking over and inundating the surrounding lands. Thousands upon thousands of acres of grain were destroyed. By the summer of 1904 the lake had dwindled to an area of about 52,000 acres, which soon entirely disappeared and in 1905 the lake bed was again dry and farming on a large scale was resumed, but this was ill-timed as subsequent events showed. The United States Geological Survey cooperating with the State of California in hydrologic research reported upon the conditions at this time in Water-Supply Paper No. 251, page 234, and following, as follows:

On March 15, 1906, the first water reached the lake bed at the mouth of Kings River and began spreading out over a large area of bottom land upon which stood a crop of wheat almost matured. A few days later water from Kaweah and Tule rivers reached the lake. Then began a steady rise which rapidly submerged an increasingly large area of wheat fields. On June 23, overflow water from [2]Kern

[1]The same was true of Tule River, ditches being taken out of both sides and running both west and south.

[2]This is said to have been the first time in twenty-five years that Kern River water reached the lake.

basin cut through the sand ridge to the south and flowed into the lake, which for a few days afterwards rose at the rate of 0.2 feet a day. On August 4, the water reached its greatest height for the year 1906 and the lake had an area of about 300 square miles and a maximum depth of 12.7 feet.

During the ensuing winter the water continued to rise so that in July, 1907, it had reached a depth of 14 feet and covered practically the same area surveyed in 1880.

Since 1907 the waters of the lake have continued to fluctuate, alternately rising and falling but with a general downward trend. On June 30, 1912, the gauge showed a depth of 8.2 feet, and in the summer of 1914 it was again dry, with nearly the whole bed under cultivation.

Each time that the levees have been destroyed they have been rebuilt or new ones constructed upon other alignments, and each time they were made stronger and higher, but never according to any systematic plan. Each owner, or group of owners forming a district, has been intent upon saving his own land from flooding instead of all joining in a comprehensive scheme that would afford protection to all. During the last few years, some small districts have been consolidated into larger bodies, and by thus combining resources have been able to build better levees, but still there is not the concert of effort that must obtain before the reclamation of Tulare Lake can become a fact.

Fortunes have been expended in attempts to develop these lands—and lost. Other fortunes are being invested in further attempts. Dredges are at work building levees, but each unit is working independently—independently and in a measure antagonistically.

In discussing the hitherto futile attempts to reclaim the bed of Tulare Lake in the report of this Department for 1912 it was said:

> It is greatly to be regretted that the interests owning this great body of a half million acres of fertile lands capable of high development could not be united into one strong organization, which would be able to effect a complete reclamation of the whole at a much smaller unit cost than that being obtained by divided effort and which will always be precarious.

It may be observed that not all whose interests lie in this region are indifferent to the advantages to be gained by the union of effort mentioned as requisite to a complete reclamation of the basin, and a sentiment has been expressed among the owners in favor of having the Sacramento and San Joaquin Valley Drainage District extended to embrace the Tulare Lake Basin.

In support of such extension it is pointed out that conditions affecting the disposition of the waters of Kings River have greatly changed in late years. Where formerly all of the water of that stream ran into Tulare Lake excepting in extremely high floods, now only a minor part of any flow reaches the lake, but runs across the divide before mentioned into Fresno Slough and thence to the San Joaquin River. When the quantity is not excessive it is intercepted and used for irrigation, but

owners of land bordering on the San Joaquin express a fear that should such floods occur as have been known upon Kings River it would be beyond the ability of existing works to control, and the accession of its flood waters to the already engorged flood of San Joaquin River would tax the reclamation works along that stream beyond their strength. Should Tulare Basin also be filled and add to the flood it is declared the results to the lands of the San Joaquin would be disastrous.

Upon the other hand, should the Kings River weirs, gates and embankments be sufficient to prevent its flood running to the San Joaquin, the waters would be turned into Tulare Lake with destructive results.

It is contended by some of each of the conflicting interests: (1) those directing the controlling works in Kings River; (2) the owners of San Joaquin reclaimed lands, and (3) those owning threatened lands in Tulare Lake, that the problem of handling the matter so as to safeguard all of these interests can only be solved by correlating and uniting them in one project.

It is urged with strong emphasis that since one of those interests is already embraced in the Sacramento and San Joaquin Drainage District the logical method of effecting the desired union of effort is to extend that district to include the lands subject to overflow in Tulare Lake Basin.

It seems equally logical, then, to go farther and include Kern Lake basin, since the works erected in Tulare Lake will be subject to danger from the waters of Kern River whenever they shall get beyond the control of local restraint.

Two large river systems traversing seventeen counties, having 600 miles of open navigable waters, carrying a recorded combined flood discharge of more than a million cubic feet of water per second, a maximum annual flow of 54,678,000 acre-feet, and a mean annual flow of 40,950,000 acre-feet; bringing devastation and ruin to a million acres of fertile land and threatening and endangering two million acres more; affecting navigation upon 600 miles of navigable waters present problems too big to be solved by the disconnected efforts of reclamation districts or even by county organizations, but must be handled as one project administered by one body supported by the power and resources of the state.

It is, therefore, recommended that by proper legislative enactment the boundaries of the Sacramento and San Joaquin Drainage District be extended so as to include the Tulare Lake Basin and the Kern Lake Basin.

Flood control problems in California are not confined to Sacramento and San Joaquin valleys. Other communities have been moved to ask the Department of Engineering for assistance, but it is out of its power

to do so excepting to give such advice as the experience of the department qualifies its engineers to offer. This has been freely done, but it is not enough.

Streams other than those above discussed are given to devastating floods. In 1904 the Colorado River forsook its channel and for three years poured its floods into the Imperial Valley, causing millions of dollars damage and the expenditure of more than $2,500,000 in closing the break and constructing works to prevent a recurrence of the disaster.

Only a few months ago a flood in Los Angeles River spread through the city and over the adjacent country, inflicting immense loss of property. Such conditions, if allowed to recur, threaten the integrity of Los Angeles harbor.

In both of these instances it is claimed that to provide adequate protection is beyond the resources of the communities to furnish without great sacrifice unless state aid in some form be extended.

Financial as well as engineering assistance has been given to stricken communities on Eel River and Mad River, but in a small way, financially.

It is suggested that if it be the policy of the state to lend aid to such enterprises it should be done in every case upon an equal basis, and that the expenditure of public moneys or of moneys obtained through state credit should be made under the direction of state authority.

It has been further suggested that such enterprises as above contemplated should be administered by some such agency as the State Reclamation Board; looking to the State Department of Engineering to conduct investigations, design plans and supervise the construction of works, all in conjunction with the local governing board and engineering force of each project in the same way that now obtains in the Sacramento and San Joaquin Drainage District project.

THE DEBRIS PROBLEM.

The discovery of gold in Sutter's mill race at Coloma in 1848 by John Marshall resulted in the development of an industry which in an incredibly short time drew hundreds of thousands of men to a practically unknown land. The hitherto silent canyons and hillsides now rang with the clink of pick and shovel and echoed the roar of rushing water through great monitors. Swarming over hills and into every nook and cranny for a third of a century these hordes of brawny, restless miners feverishly dug and washed for gold, unconscious of the havoc this work would cause below. It is said that thirty thousand of his busy kind were counted at one time on the Yuba and its tributaries. Whole mountain sides were torn down, and the earth and gravel and stones sent rushing through long sluices and into the river channels to be carried

farther and farther, and finally dropped on the beds of quieter streams in the valley. No one gave thought of the consequences of sending this avalanche upon the lowlands.

But soon a pastoral race arrived, and engaging in the more quiet occupation of tilling the fertile valley, quickly found the increasing accumulation of mining debris becoming a menace to their land. The channels of the navigable streams became clogged with the ever-increasing volume of sand sent down from the mines until in the interests of navigation the federal courts enjoined the miners from operating hydraulic mines and that great industry came to a standstill.

In 1893 the "Caminetti Act" was passed by the congress of the United States authorizing hydraulic mining to be conducted wherever by restraining dams the debris could be prevented from reaching the streams. Under these restrictions mining was resumed and conducted to a limited extent. The law, just mentioned, created the California Debris Commission, and in addition to its powers to supervise and restrain mining it was enjoined to devise plans for the improvement and protection of the navigable waters. The Commission consists of three officers of the Engineer Corps of the United States Army.

After six or seven years spent in investigation and study of the conditions and problems presented, the Commission selected the Yuba River as the first point of attack. The conditions on this stream seemed to demand most urgently the remedial measures proposed. A discussion of the conditions which led to the adoption of the plans for debris control on the Yuba River may properly be presented here.

Before this river became the carrier of the great mass of debris liberated by the miners working on its tributaries, it is described as having been a clear stream flowing between well-defined banks. The distance from its confluence with Feather River to the mouth of the canyon, where it debouches into the Sacramento Valley, just above Daguerre Point, is something more than 11 miles.

The canyon at its mouth is more than a mile wide, but gradually narrows as one goes upstream until at the site of the barriers, some four miles above the mouth, it is considerably less than a half mile in width. After emerging from the canyon the gradient becomes less steep, causing a diminution of the velocity of the moving water and a corresponding reduction in its transporting power. It then begins to drop its load, first the heaviest then the lighter material and carrying the lightest even as far as the sea.

Bringing so much debris out of the hills and depositing it in the channel of lesser grade, soon gorged the channel, causing the water to spill out at the sides and seeking the lowest place soon formed other channels. These in turn filled up and still others were formed, shifting first one way and then another until eventually a wide expanse of the plain was

covered. This building-up process continued until the bed of the river covered a space nearly three miles wide, comprising about 25 square miles in area, and extending from Feather River to the hills. This space is sometimes called the Yuba Debris Basin. The depth of this great mass is from 8 to 26 feet, and the volume is variously estimated at from 360,000,000 to 600,000,000 cubic yards.

As the river built up its bed and continued to spread over the adjacent country, the farmers constructed levees to protect their lands from the overflow, so there is now a strong levee on each side, extending from the Feather River to the foothills, and enclosing the debris basin.

Back in the mountains there are yet stores of debris lodged in the "pockets" or holes in the bed of the rivers, and in the side canyons. Each recurring flood dislodges portions of this debris and brings it down to add to that already deposited in the lower levels.

For many years the increase of the deposit in the debris basin was shown by measurements to be about three million cubic yards a year. As the river would bring down a load of material and deposit it, the water would pick up a lighter load and carry it down into the streams below, where it would again be dropped. This constant migration of debris was so great as to practically destroy navigation on the Feather River and caused the Debris Commission to recommend, about 1899, that no more effort be made to maintain navigable conditions on the Feather until the downflow of debris from the Yuba should cease.

Now, when the stores of debris in the mountains shall have been exhausted, and the river shall have no more to deposit, it will continue to pick up the materials it has formerly dropped in the debris basin and carry them as far as the transporting velocity obtains. Reversing the process by which the debris basin was filled, the stream if not restrained would move from one location to another and continue to erode its channels through the great accumulation until it had cut its bed down to a stable hydraulic gradient. In doing this it would transport a very large portion of the hundreds of millions of cubic yards of materials stored in the debris basin.

The plan adopted by the Debris Commission for the treatment of the problem on the Yuba River was, briefly, as follows:

(1) Barriers were designed to arrest the downpour of debris from the mountain stores.

(2) Settling basins were devised to impound the debris arriving in excess of the storage capacity of the barriers.

(3) Training walls were planned to confine the river within fixed limits on its course through the debris basin, so that it should not eventually carry down more than the volume contained in the prism between the walls.

A fund of $800,000 had been provided, $400,000 each, by the Federal Government and the State of California, for carrying out the project proposed. Delays were encountered in procuring the necessary rights of way so that not until 1902 could actual construction be commenced.

Four attempts were made during the ensuing five years to construct and maintain barriers in the river above the mouth of the canyon according to the plans, but each time the work was destroyed by the following floods. These barriers were located a short distance below the old mining town of Smartsville. At each attempt to build a barrier the plan was changed from the previous one. The last one, constructed in 1905, was completed to a height of 14 feet above the bed of the stream and provision made for raising it to an ultimate height of 30 feet, as the accumulation of material above it should require. The flood of March, 1907, utterly destroyed it, and the plan to erect barriers in the canyon was abandoned.

While construction of the barrier described was in progress, work on the other features of the project was being prosecuted, to wit: a barrier across the mouth of the canyon, one of the settling basins and the training walls.

The South Settling Basin, situated outside of the debris basin and south of it was completed with concrete inlet and outlet gates. It covered about 1,818 acres and was estimated to have a storage capacity of 8,161,000 cubic yards of sediment. It was, however, never used and by authority of congress was sold in 1911 for $27,500 which sum was credited to the United States appropriation for the project.

Thus was eliminated from the original plans the barriers in the canyon and the settling basin. There still remain the barrier at the mouth of the canyon and the third feature of the project, the training walls, to discuss.

These works have been constructed largely with gold dredges in the course of their dredging for gold which had escaped from the miners sluices in the mountains and came down with the debris from the mines. These monster machines, costing $125,000 to more than $300,000 dig to a depth, sometimes of 70 feet or more below the surface of the ground. All materials are brought up and screened or washed. The cobbles, measuring to one or two cubic feet, are piled at random 20 to 30 feet high.

An arrangement was made with the companies operating the dredges whereby their operation should be conducted where indicated by the Debris Commission, and in such manner as to form a cobble barrier and the training walls required.

This barrier or dike starts at Hallett Point on the south side and runs across the river bed, first diagonally upstream for some distance and then turning sharply downstream crosses the channel and connects

with Daguerre Point on the north side. By this arrangement a basin is created on the upstream side of the barrier.

In order that the river should not rise above the top of the barrier and flow over it a new channel was provided by making a cut through Daguerre Point. This cut is 700 feet wide, excavated in solid material, and provided with a concrete lip or sill across the intake to prevent erosion. In this way a stable channel is provided at a depth far enough below the top of the barrier to prevent the water overtopping the latter and at the same time the sill will prevent the channel cutting down and allowing the stored debris to escape.

The storage capacity of the basin above the cut and barrier is estimated at about 60,000,000 cubic yards.

According to the plans of the project, which have been adhered to as far as they have been completed, the training walls begin at Daguerre Cut and are to extend to Feather River. They are designed to be about 2,000 feet apart in the upper portion and approach nearer together as they progress downstream.

They were mainly constructed by the gold dredges above described, the work of which has been so conducted as to leave two immense cobble dikes, 20 or 30 feet high and 200 to 300 feet wide at the base, one on each side of the intended channel to confine the river in its prescribed course. The walls extend from the mouth of the cut for about one third of the distance to the mouth of the river at Marysville.

The route of the proposed channel is kept cleared of timber and brush so as to offer the least obstruction to the water following the intended course. From examination of physical conditions along the Yuba River the following changes seem to have occurred:

The stores of debris in the canyons is becoming depleted so that the quantity brought down from the mountains is much less than formerly;

The arrest of the flowing debris in the basin above the Daguerre barrier makes a marked diminution in the quantity carried below the barrier;

The confining of the river to a defined channel and lessening of its load of debris has caused it to lower its hydraulic grade line and materially lower the flood plane in the vicinity of Marysville.

The two last are the effects of the works installed by the Debris Commission, and it is confidently believed that further beneficial results will soon be apparent in a decrease of sand deposits in Feather River.

During the last biennial period the principal work accomplished in the Yuba project has been raising the sill at the intake of Daguerre Cut so as to increase the storage capacity of the debris basin above. The new work is finished with a timber cap as it is believed replacing it will be less expensive than repairs to a concrete finished sill made necessary on account of the rapid abrasion by the sand-laden water.

The work relating to debris control and improvement of navigation in the streams of California is under the direction of the Debris Commission. The officers of the United States Engineer Corps, composing the Commission during the last two years were Lieutenant Colonel Thos. H. Rees, Lieutenant Colonel C. H. McKinstry and Major S. A. Cheney, in 1912-13, and Lieutenant Colonel Rees, Major R. R. Raymond and Major Cheney during 1913-14.

EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
WASHINGTON, August 11, 1913.

CALIFORNIA DEBRIS COMMISSION.

Unrestricted mining by the hydraulic process in California resulted in enormous quantities of debris being washed down into the rivers and natural watercourses draining the western slope of the Sierras. Later on hydraulic mining was practically prohibited by the decisions of the courts on account of injury to streams and the adjacent private land.

The act of congress approved March 1, 1893, created the California Debris Commission and provided that the commission should consist of three officers of the corps of engineers appointed by the President, with the concurrence of the senate. The same act prescribed the duties of the commission, which are, first, the regulation of hydraulic mining in the territory drained by the Sacramento and San Joaquin River systems (shown on map opposite page 2492, part 3 of the Annual Report of the Chief of Engineers, United States Army, for 1881), so that mining by that method may be resumed and carried on without injury to other interests in the state, and, second, to mature and adopt plans to improve the navigability of the above-mentioned river systems, to protect same from damage due to mining debris, and to afford relief thereto in flood time.

Regulation of hydraulic mining and plans for improvement and protection of rivers and control of flood waters and mine debris. The operations during the fiscal year ending June 30, 1913, consisted of regulating hydraulic mining in the drainage areas of the Sacramento and San Joaquin River systems to the end that the debris resulting from such operations should be restrained and impounded by the operators of the mines in the vicinity of the latter, and thus prevent it from reaching and causing damage to navigable streams or increasing the existing flood problems in Sacramento and San Joaquin valleys. Examinations and surveys were also made in the drainage area of the Sacramento River to obtain detailed data needed in connection with the preparation of plans for the improvement of navigation, control and disposition of mine debris, and control of flood waters in the drainage area of that stream.

From time of its creation in 1893 up to June 30, 1913, the commission has received 897 applications for permits to mine by the hydraulic process under the requirements of the act of congress of March 1, 1893, and has granted permits in cases where means for properly impounding the debris were provided by the applicants. During that time the commission has also made numerous necessary examinations and surveys of portions of the Sacramento, San Joaquin, Feather, Yuba, Bear, American, Mokelumne, and other streams comprising the Sacramento and San Joaquin River systems, and prepared and submitted general plans and projects for the storage of mine debris in Yuba River and for the control of floods and debris in the Sacramento and Feather rivers. The general project for the control of mine debris in Yuba River was printed, with maps, in House Document No. 431, fifty-sixth congress, first session, and without maps in the annual report of the

Chief of Engineers for 1900, part 8, page 5030–5070. This general project was adopted by congress and by the legislature of the State of California, each appropriating one half the estimated cost of the work. Further information concerning the details of this project and the progress of operations under it are given below, under the subheading "Storage of mine debris in Yuba River, Cal."

The general project for the control of floods and debris in the Sacramento and Feather rivers, the preparation of which involved a large amount of research and investigation, was printed, with maps, in House Document No. 81, sixty-second congress, first session. This general project has been adopted by the legislature of the State of California in its entirety, and partially by congress, that is, to the extent of appropriating $400,000 for beginning the work contemplated in the commission's preliminary report dated June 30, 1907. (Report printed in the annual report of the Chief of Engineers for 1907, pages 2262–2269.)

Further information concerning the details of the project for the control of floods and debris in the Sacramento and Feather rivers and the progress of operations under it are given below, under the subheading "General project for control of debris and floods in the Sacramento and Feathers rivers." As therein indicated as the result of the enormous development work which has been carried on in Sacramento Valley by numerous local enterprises since the project printed in House Document No. 81, above referred to, was prepared, the commission was able during the past year to make a very material reduction in the estimate of cost of the work remaining to be done.

The $15,000 given in the appended money statement as the amount required for expenses of the California Debris Commission during the fiscal year ending June 30, 1915, is required to continue during that year the work of regulating hydraulic mining operations and to continue the work of making examinations and surveys in the Sacramento and San Joaquin valleys for the improvement of navigation, control and disposition of mine debris, and control of flood waters, as required by the act of congress approved March 1, 1893.

Storage of mine debris in Yuba River, Cal. Following the act of March 1, 1893, creating the commission, Yuba River, a tributary of the Feather, which in turn is a tributary of the Sacramento River, was first considered for treatment, this stream being more filled with debris and carrying more detritus than all the other tributaries of the Sacramento combined. The general project for the treatment of the Yuba was printed with maps, in House Document No. 431, fifty-sixth congress, first session, and without maps in the annual report of the Chief of Engineers for 1900, part 8, pages 5030–5070. The estimated total cost of this project was placed at $800,000. It was adopted by act of congress approved June 13, 1902. The estimated total cost of the project has been appropriated, $400,000 by congress and $400,000 by the legislature of California, the appropriations by congress stipulating that one half the cost of the work should be paid by the State of California.

The Yuba River project contemplated holding the great quantities of mine debris now in that stream and tributaries to prevent it from being carried down into the Feather and Sacramento rivers, this to be accomplished by restraining barriers or dams across the bed of the Yuba, by a storage or settling basin adjoining the river on the south in the vicinity of Daguerre Point, and by training walls below, all as located on Map No. 5 (sheet A), printed with House Document No. 431, above referred to.

Later on barrier No. 1, barrier No. 2, and the flood overflow barrier, shown on map No. 5, above referred to, were eliminated from the project, as was also the storage or settling basin in the vicinity of Daguerre Point. Operations have since been confined to the Daguerre barrier and the works connected therewith in Daguerre Point Cut and to the construction of training walls below Daguerre Point.

The operations during the past fiscal year consisted of making a survey of Yuba River from Parks Bar Bridge, below the Narrows, down to its mouth in Feather River and preparing plans and specifications for protecting and raising the inlet wall constructed across Daguerre Point Cut in 1906. These operations were on account

of new work. The expense was paid, one half by the United States and one half by the State of California.

The total amount expended by the United States on the project up to June 30, 1913, was $348,013.81, for works of improvement. The State of California has expended a like sum on the work. The sum of $28,279.48 has been received by the United States from sales of land and other property. The expenditures by the United States have been principally in payment of one half the purchase price of upward of 10,000 acres of land, in payment of one half the cost of the construction of portions of barriers Nos. 1 and 2, one half the cost of excavating a channel through Daguerre Point and constructing a concrete inlet wall across the cut, of one half the cost of constructing a portion of the training walls below Daguerre Point, of one half the cost of constructing a portion of the storage or settling basin on the south side of the river in the vicinity of Daguerre Point, and of one half the cost of clearing trees and brush from the flood channel from Daguerre Point to Marysville, Cal.

The works thus far constructed have resulted in restraining many million cubic yards of mine debris in Yuba River above Marysville. No additional funds are needed for operations in the fiscal year ending June 30, 1915, the available balances of appropriations heretofore made by congress and the legislature of California being sufficient for carrying on such operations as may be necessary during that year.

General project for control of debris and floods in the Sacramento and Feather rivers. The conditions along the Sacramento and Feather rivers were set forth in detail in House Document No. 81, sixty-second congress, first session. In a preliminary report, dated June 30, 1907, printed in the Annual Report of the Chief of Engineers for 1907, pages 2262-2269, the Commission stated that dredging was considered the most feasible method to meet the requirements of all the interests involved —navigation, protection from flood overflow, better drainage and disposal and control of debris in the Sacramento and Feather rivers—and submitted an estimate of $800,000 for the beginning of this work. In submitting this estimate the commission expressed the opinion that one half should be provided by the State of California. The State of California on March 1, 1909, appropriated $400,000 for this purpose, with the stipulation that—

> SEC. 2. This act shall become operative only upon condition that the government of the United States shall, under, by, and through the War Department, assume full charge and control of all work to be done as provided by this act, and also upon condition that a like sum of four hundred thousand dollars be appropriated by the United States for such work.

The appropriation made by the State of California also contained the provision that—

> The whole of such amounts appropriated by the congress of the United States and by the State of California shall be expended under the direction of the Secretary of War and the supervision of the Chief of Engineers.

The river and harbor act approved June 25, 1910, appropriated $400,000 for this work, as follows:

> Improving Sacramento and Feather rivers, California: Continuing improvement and toward the controlling of debris and floods, in accordance with the recommendations of the California Debris Commission in its report dated June thirtieth, nineteen hundred and seven (printed in the Annual Report of the Chief of Engineers, United States Army, for nineteen hundred and seven, pages twenty-two hundred and sixty-two to twenty-two hundred and sixty-nine, inclusive) four hundred thousand dollars; *provided*, that no part of this sum shall be expended unless the State of California shall appropriate for the prosecution of said project a like sum of four hundred thousand dollars and deposit the same in the treasury of the United States; *provided further*, That the treasurer of the United States is hereby authorized to receive from the State of California any and all sums of money that have been or may hereafter be

appropriated by said state for the purpose herein set forth; and when so received the said sums are hereby appropriated for said purpose, to be expended under the direction of the Secretary of War and the supervision of the Chief of engineers; *and provided further*, that the work herein provided for shall not be begun until all rights of way needed for levees and spoil banks have been furnished the United States free of cost.

In compliance with the requirements of the act of congress the authorities of the State of California deposited the state's appropriation of $400,000 in the treasury of the United States on July 1, 1911.

The first work proposed to be done under this project is to afford relief from floods along the lower portion of the Sacramento River (shown on sheet E of maps printed with House Document No. 81, sixty-second congress, first session) by increasing the flood-carrying capacity of that portion of the river.

During the past fiscal year all the land needed for carrying on the operations to the extent permitted by the $400,000 appropriated by the state on March 1, 1909, and $400,000 appropriated by the act of congress of June 25, 1910, was furnished the United States free of cost, as required by the last named act, and two suction dredges, including pontoons and pipe lines, and a dredge tender were practically completed.

The amount expended up to the close of the fiscal year ending June 30, 1913, was $417,490.93 for works of improvement. Of this amount $400,000 was from the appropriation of congress of June 25, 1910, and $17,490.93 from the appropriation made by the State of California March 1, 1909.

These expenditures were for the construction and partial equipment of the two suction dredging plants, above referred to, and getting them ready for actual operation early in the coming fiscal year.

The Committee on Rivers and Harbors of the House of Representatives passed the following resolution December 2, 1912:

> *Resolved by the Committee on Rivers and Harbors of the House of Representatives, United States,* That the Board of Engineers for Rivers and Harbors, created under section 3 of the river and harbor act approved June 13, 1902, be, and it is hereby requested to examine and review its report of December 27, 1910, upon the navigation and flood control of the Sacramento and San Joaquin River systems, California, printed in House Document No. 81, sixty-second congress, first session, and to report its subsequent information and conclusions thereon.

In response to a request from the Board of Engineers, for Rivers and Harbors to the Chief of Engineers, the California Debris Commission was called upon for a report as to any subsequent information bearing upon the report referred to in the above-quoted resolution. In response thereto the Commission submitted a report on February 8, 1913, in which the following facts were set forth:

In the Commission's report, submitted August 10, 1910, and printed in House Document No. 81, sixty-second congress, first session, the estimated cost of all the work therein proposed was placed at $33,000,000, and the Commission therein expressed the opinion that the State of California would be benefited to the extent that it should provide two thirds of this amount, leaving the remainder, $11,000,000, to be provided by the United States. In its subsequent report, dated February 8, 1913, submitted to the Chief of Engineers consequent to the above-quoted resolution of the Committee on Rivers and Harbors of December 2, 1912, the Commission pointed out that since the 1910 report there had been a period of tremendous development in the Sacramento Valley in the way of extensions of old and construction of new steam and electric railroads, and strengthening of old levees to better protect lands already reclaimed, and construction of new levees to reclaim additional large areas of land, that the existence of the 1910 report and its adoption by an act of the legislature of the State of California, approved December 24, 1911, had led the many large interests engaged in development work to adopt the plan of the Commission as the approved plan for control of floods in the Sacramento Valley and its

tributaries, and that these large enterprises in the valley had been constructed or planned not only so as not to encroach upon the Commission's plans, but on the contrary to form a part of the works included in the Commission's plans. Thus it was found that much of the work planned by the Commission had already been done or arranged for by private enterprises, making it possible to eliminate much of the work and expense which had been contemplated in the Commission's 1910 report. The Commission's report of February 8, 1913, contained an estimate of $11,717,008, as the total cost of the works necessary for the control of debris and floods and improvement of navigation in accordance with the plans contemplated in the 1910 report, after deducting from the 1910 estimates the works since constructed or projected in conformity therewith by private enterprises, and also after deducting the $400,000 appropriated by congress June 25, 1910, and the $400,000 appropriated by the legislature of the State of California. In connection with the estimate of $11,717,008, the Commission expressed the opinion that one half of this amount is properly payable by each the United States and the State of California; provided, however, that all land required should be furnished without cost to the United States; and provided, also, that upon their completion all the flood-control works should be turned over to the State of California for maintenance.

The work about to be begun along the lower portion of Sacramento River with the two suction dredging plants, which are now practically completed, is a part of the work included in the 1910 and 1913 reports, toward which congress appropriated $400,000 by act approved June 25, 1910, and toward which the legislature of California appropriated $400,000 on March 1, 1909. The legislature of California has since, by act approved, June 7, 1913, appropriated $200,000 additional, bringing the state's total appropriations up to $600,000. The following is the latter act in full:

CHAPTER 452.

An act to provide for the accomplishment of the work of the direct improvement of the navigation of the Sacramento, San Joaquin, and Feather rivers, of the State of California, as recommended in the special report of the California Debris Commission, dated June 30, 1907, and made jointly by Brigadier General A. Mackenzie, Chief of Engineers, C. H. McKinstry, major, Corps of Engineers, and Thos. H. Jackson, captain, Corps of Engineers, of the United States Army, and printed with the annual report of the Chief of Engineers of the United States Army for the fiscal year ending June 30, 1907, and making an appropriation for such work.

[Approved June 7, 1913.]

The people of the State of California do enact as follows:

SECTION 1. The sum of two hundred thousand dollars is hereby appropriated out of any moneys in the state treasury not otherwise appropriated, which shall be available July 1, 1914, for the accomplishment of the work of the direct improvement of navigation of the Sacramento, San Joaquin, and Feather rivers, of the State of California, as recommended in the special report of the California Debris Commission, dated June 30, 1907, and made jointly by Brigadier General A. Mackenzie, Chief of Engineers, C. H. McKinstry, major, Corps of Engineers, and Thomas H. Jackson, captain, Corps of Engineers, of the United States Army, and printed with the annual report of the Chief of Engineers of the United States Army for the fiscal year ending June 30, 1907.

SEC. 2. The Governor of the State of California shall have charge and control of the expenditure of all moneys appropriated hereunder, and he is hereby authorized to enter into and to execute any contract or contracts with the United States Government, or any department thereof for the performance of the work, or any part thereof, provided for by this act, or to purchase materials, machinery, power, labor, or any other things necessary for such work, and generally to do any and all things necessary or proper to effectually carry into operation the work sought to be accomplished hereby.

SEC. 3. All contracts made hereunder shall provide specifically that only one half of the contract price of any work performed, or to be performed under this act, shall be paid by the state, and in case said work or any part thereof shall be performed in any other manner than by contract only one half of the expense of such work or of any matters incident thereto shall be paid by the state.

SEC. 4. This act shall become operative only upon condition that the government of the United States shall, under, by, and through the War Department, assume full charge and control of all work to be done as provided by this act, and also upon condition that a like sum of two hundred thousand dollars be appropriated by the United States for such work.

SEC. 5. The controller of the State of California is hereby authorized and directed, upon request of the Governor, to draw his warrant on the state treasurer from time to time and for such portion of said sum of two hundred thousand dollars and in favor of such person, corporation, or other parties as the Governor may designate, and the state treasurer is hereby directed and empowered to pay such warrants.

Under the terms of this state act the appropriation of $200,000 does not in any event become available until July 1, 1914, and it becomes available then only upon condition that the Government of the United States shall, under, by, and through the War Department, assume full charge and control of all work to be done and also upon condition that a like sum of $200,000 be appropriated by the United States for such work.

The $400,000 appropriation made by the state March 1, 1909, provided that that sum should be deposited in the treasury of the United States, which was done. The act of congress of June 25, 1910, authorized the treasurer of the United States to receive the same and also reappropriated it for the work referred to in the acts. The state act of June 7, 1913, does not provide that the $200,000 appropriated by it shall be deposited with the treasurer of the United States, but, on the contrary, contemplates that the state shall pay one half of each account or bill of indebtedness incurred in carrying on the work. This is the method followed on the Yuba River work.

Should congress decide to authorize this additional work at this time the amount of United States funds that can be profitably expended on this work in fiscal year ending June 30, 1915, exclusive of the balance unexpended July 1, 1913, is $50,000. This is the additional amount needed to avoid a complete suspension before the close of the fiscal year ending June 30, 1915, of the work of increasing the flood carrying capacity of the Sacramento River near its mouth, as shown on sheet E of maps printed with House Document No. 81, sixty-second congress, first session. It is recommended, however, that the full amount ($200,000) to be appropriated by the United States be made available at one time, on account of the stipulation in the act of the state legislature of June 7, 1913, appropriating $200,000 for the work, that the state's appropriation is made "upon condition that a like sum of $200,000 be appropriated by the United States for such work."

The interests of navigation, the problem of flood control, and the control and disposition of mine debris in and along the Sacramento and San Joaquin rivers and their tributaries are all inseparably connected. More extended information on these subjects may be found in the executive documents and annual reports referred to at page 1286 of the Annual Report of the Chief of Engineers for 1912, in House Document No. 581, sixty-second congress, second session, and in the report of the California Debris Commission to the Chief of Engineers of February 8, 1913, submitted consequent to the above-quoted resolution of the Committee on Rivers and Harbors of the House of Representatives of December 2, 1912.

The members of the commission during the past fiscal year were the following officers of the Corps of Engineers, United States Army: Lieut. Col. Thomas H. Rees, Lieut. Col. C. H. McKinstry, and Major S. A. Cheney.

Appropriation for expenses of California Debris Commission, 1913.

August 24, 1912, amount appropriated by act of congress approved August 24, 1912	$15,000 00
June 30, 1913, amount expended during fiscal year	9,201 45
July 1, 1913, balance unexpended	$5,798 55
July 1, 1913, balance reverting to treasury of United States	$5,798 55

Appropriation for expenses of California Debris Commission, 1914.

Amount appropriated by act of congress approved June 23, 1913	$15,000 00
Amount (estimated) required for expenses of the California Debris Commission during the fiscal year ending June 30, 1915	15 000 00

Appropriation by congress for restraining mine debris in Yuba River, California.

July 1, 1912, balance unexpended	$82,250 53
Received from sales	30 00
	$82,280 53
June 30, 1913, amount expended during fiscal year for works of improvement	2,014 86
July 1, balance unexpended	$80,265 67
July 1, 1913, outstanding liabilities	11 63
July 1, 1913, balance available	$80,254 04

General project for control of debris and floods in the Sacramento and Feather rivers, California.

July 1, 1912, balance unexpended (including $400,000 contributed by the State of California)	$668,276 18
June 30, 1913, amount expended during fiscal year, for works of improvement	[1]285,767 11
July 1, 1913, balance unexpended	$382,509 07
July 1, 1913, outstanding liabilities	13,486 26
July 1, 1913, balance available	[2]$369,022 81

([1]In addition there was expended during the year $921.99 from appropriation for fiscal year 1912.)

([2]Exclusive of $200,000 appropriated by act of California state legislature of June 7, 1913.)

July 1, 1913, amount covered by uncompleted contracts	$1,500 00

Amount (estimated) required to be appropriated for completion of existing project, indeterminate. (See Appendix ZZ.)

APPENDIX ZZ.

ANNUAL REPORT OF THE CALIFORNIA DEBRIS COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1913.

CALIFORNIA DEBRIS COMMISSION,
SAN FRANCISCO, CAL., July 1, 1913.

SIR: The California Debris Commission submits the following annual report for the fiscal year ending June 30, 1913:

REGULATION OF HYDRAULIC MINING AND PLANS FOR IMPROVEMENT AND PROTECTION OF RIVERS AND CONTROL OF FLOOD WATERS AND MINE DEBRIS.

Regulation of hydraulic mining in the drainage areas of the Sacramento and San Joaquin River systems. During the fiscal year the commission received eight applications for permits to mine by the hydraulic process under the provisions of the act of congress approved March 1, 1893, as amended by the act approved February 27, 1907.

During the same period three permits to mine by the hydraulic process were granted, the applicants in these cases having constructed the necessary dams or barriers to impound the debris resulting from their mining operations so as to prevent it from reaching the navigable streams.

As in former years, numerous personal inspections were made of the hydraulic mining region and of mines and their works for impounding debris. During the

year legal proceedings instituted in previous years in a number of cases of illegal hydraulic mining operations were brought to a conclusion in the United States court, fines being assessed by the court in all such cases.

Plans for improvement and protection of rivers and control of flood waters and mine debris. Under the provisions of the act of congress approved March 1, 1893, the Commission is required to mature and adopt such plans from examinations and surveys already made, and from such additional examinations and surveys as may be deemed necessary as will improve the navigability of all the streams comprising the Sacramento and San Joaquin river systems, deepen their channels, and protect their banks, such plans to be matured with the view of making the same effective as against the encroachment of and damage from debris resulting from mining operations, natural erosion, floods, and other causes. Several surveys were made during the past year in the Sacramento Valley to obtain data needed in formulating plans for these purposes, and many meetings were held at which the numerous problems involved were considered and discussed with persons and representatives of corporations interested in transportation, reclamation, irrigation, flood control, and mining.

The expenditures during the fiscal year ending June 30, 1913, for regulating hydraulic mining and making examinations and surveys for improvement of navigation, control, and disposition of mine debris, and control of flood waters amounted to $9,201.45.

The work proposed during the fiscal year ending June 30, 1914, with the $15,000 appropriated by the act of congress of June 23, 1913, is as follows:

Making examinations and surveys for improvement of navigation, control and disposition of mine debris and control of flood waters:	
In drainage area of San Joaquin River	$11,500 00
In drainage area of Sacramento River	2,500 00
	$14,000 00
Regulating hydraulic mining in the drainage area of the Sacramento and San Joaquin rivers	1 000 00
Total	$15,000 00
Amount (estimated) required for expenses of California Debris Commission during the fiscal year ending June 30, 1915, in regulating hydraulic mining operations, making examinations and surveys for improvement of navigation, control and disposition of mine debris and control of flood waters in the drainage areas of the Sacramento and San Joaquin river systems, as required by the act of congress approved March 1, 1893	$15,000 00

STORAGE OF MINE DEBRIS IN YUBA RIVER, CALIFORNIA.

The operations during the past year under the general project for storing mine debris in Yuba River, under appropriations made by congress and the legislature of the State of California, have been as follows:

Training walls. The work of constructing the gravel embankments (referred to at pages 2929-2930 of the annual report of 1911) by means of gold dredges to confine and control the flow of Yuba River in the vicinity of Daguerre Point about 10 miles above Marysville, under agreement with W. P. Hammon and associates, was continued.

Survey, Parks Bar bridge to Feather River. During the past fiscal year a survey was made of the Yuba River from Parks Bar bridge down to its mouth in Feather River, a distance of 18 miles. This survey was made to determine the extent of the debris movement that has occurred since preceding surveys were made, and to furnish the information necessary for planning further works.

Comparison of this survey with that of 1906 shows that the great movement of debris into the lower Yuba River from the mountain sections, which it was estimated much greater during preceding years, has practically ceased. Since 1906 the two amounted to a fill of 18,000,000 cubic yards between 1899 and 1906, and which was largest floods, during the period within which reliable records have been kept, occurred. Considerable local movement of debris in the bed of the lower river has taken place. This has been greatly lessened by the Daguerre Point barrier

checking the movement from above, and by the training wall and by the clearing of timber to encourage the formation of a stable channel of sufficient capacity to pass the floods.

Surveys and observations made during the year give grounds for the belief that the rivers in the district are gradually working out of the unfavorable condition arising from the enormous amount of debris thrown into them during the period of unrestricted hydraulic mining.

Cross-sections of the Yuba River bottoms, from The Narrows near Smartsville to the mouth at Marysville, made during the fall of 1912, when compared with the survey of this area made in 1906, while showing cut in some sections and fill in others, attributable to certain causes, such as the turning of the river through the Daguerre Point cut, the extension of the training walls below Daguerre Point, a break in the Linda (south) levee and the clearing of brush along the main channel, indicate that taken as a whole, there has been a slight reduction in the total amount of debris in the area considered and that the river is cutting down through the debris deposits below Daguerre Point into a fairly deep and permanent channel.

The Feather River from the mouth of the Yuba, at Marysville, to its junction with the Sacramento, at Vernon, is still heavily charged with sand, which appears to be coming down faster than the Sacramento can take care of it. Last summer a bar with less than three feet of water on it formed quite across the Sacramento at the mouth of the Feather, where our surveys of 1907 showed an ample channel over 20 feet deep. This latter condition probably resulted from breaks in the levees that occurred shortly before the 1907 survey was made, and the present condition may be attributed to the extreme low flow obtaining in Sacramento River during the summer of 1912. A similar effect was noticed below the mouth of the American River last summer, and dredging was necessary there, as well as at the mouth of the Feather, to maintain the project depth of 4 feet. Even lower stages are indicated for the present summer (1913), and considerable work will be necessary to maintain the channel between Sacramento and the mouth of the Feather.

In spite of the low flow last year, less difficulty than usual was experienced in navigating up to Sacramento, although some dredging was necessary immediately below the city to maintain the 7-foot channel.

The Weather Bureau gauge at Sacramento showed the lowest reading (4.1 feet) that has been noted for over forty years. This was not entirely due to the low discharge for lower discharges have occurred in this period, but rather to the fact that the river bed is working down to the condition obtaining before the days of unrestricted hydraulic mining. The following table of average low water readings at Sacramento, by five-year periods, compiled from such data as are available, will serve to indicate the effect of mine debris on the river stages at this point:

Average low water at Sacramento for five-year periods, 1849-1912.

	Feet
Average gauge reading:	
1849–1853, five observed years	0.6
1854–1858, five observed years	1.2
1859–1863, three observed years	2.2
1862–1873, no records.	
1874–1878, five observed years	5.5
1879–1883, five observed years	6.5
1884–1888, five observed years	7.3
1889–1893, four observed years	7.8
1894–1898, five observed years	8.0
1899–1903, five observed years	7.2
1904–1908, five observed years	6.8
1909–1912, four observed years	5.1

The records indicate that the water reached zero on this gauge in 1849 and again in 1856. The peak of the debris effect appears to have been reached in 1896 at a reading of 8.5, although in 1890 a reading of 9.3 occurred. Over a foot of tide was noted during low-water stages last summer.

Inlet wall at Daguerre Point Cut. In 1903-1906 a cut involving the removal of 634,207 cubic yards of earth and rock, was excavated through Daguerre Point on the approximate lines shown on sheet A, printed with House Document No. 431, fifty-sixth congress, first session. The dimensions of the cut, etc., as completed, were given in the annual report of the Chief of Engineers for 1904, pages 3705-3706. In 1905 and 1906 a concrete inlet wall, with the necessary abutments, was constructed across this cut. A photograph of this wall as completed in 1906, and plans of it, marked "Appendix B," precede page 2079 of the annual report for 1906. For several years prior to 1911 the work of throwing up a dam of gravel and cobbles, extending entirely across the channel of Yuba River in the vicinity of Daguerre Point, to force the entire flow of the stream through the cut excavated through Daguerre Point, had been in progress. This dam of gravel and cobbles was thrown up by gold dredges operating in the vicinity. It was constructed approximately along the line of the structure marked "Daguerre barrier," sheet A, above referred to.

The diversion of the river through the cut was accomplished during the summer of 1910, and since that time the full flow of the stream has passed over the inlet wall in the cut. The construction of these works resulted in impounding in the Yuba River above them many million cubic yards of mine debris, thus preventing the debris from reaching the Sacramento and Feather rivers below to the detriment of navigation in these streams.

At high water more or less sand and gravel is carried over the inlet wall, causing erosion of its concrete surface. This erosion has continued since 1910 until about 50 per cent of the surface has been worn down from 1 to 3 inches, and numerous pockets 4 to 6 inches deep have developed. Plans and specifications have recently been prepared for raising the inlet wall and facing it with timber. Erosion tests were made on samples of oak, maple, eucalyptus, and Oregon pine, which indicated that the resistance to erosion of the harder woods was not in proportion to their higher cost in this locality. These tests demonstrated that, service and cost considered, Oregon pine is the most suitable material for the proposed timber facing, and the plans and specifications were therefore made to provide for the use of that kind of timber.

This proposed work will raise the effective height of the inlet wall about 16 inches and add approximately 3,000,000 cubic yards to the storage capacity for mine debris produced by the Daguerre Point barrier.

It is proposed to invite bids for this work at once and complete it, if practicable, before the high-water season of 1913-14.

The expenditures during the year were as follows:

Survey, Parks Bar Bridge to Feather River	$3,484 66
Plans for raising the inlet wall at Daguerre Point Cut	545 06
Total	$4,029 72
Amount (one half) paid by the State of California	2,014 86
Balance (one half) paid by the United States	$2,014 86

The work proposed during the fiscal year ending June 30, 1914, consists of raising the inlet wall in Daguerre Point Cut and facing it with timber, at an estimated cost of $15,000, one half of which amount is payable by the United States and one half by the State of California. It is also proposed to continue the work of constructing gravel embankments by means of gold dredges under agreements with W. P. Hammon and associates.

These embankments are being constructed without cost to the United States and State of California; no expenditure of government funds or state funds on them are involved.

Appropriations by Congress.

June 3, 1896	$250,000 00
June 13, 1902	150,000 00
	400,000 00
Received from sales	28,279 48
Total	428,279 48

GENERAL PROJECT FOR CONTROL OF DEBRIS AND FLOODS IN THE SACRAMENTO AND FEATHER RIVERS.

The scope of this project is set forth under the above heading in the summary of this report.

The operations during the past fiscal year have been as follows:

Constructing and equipping dredging plants. The construction of the two 20-inch suction dredges "Sacramento" and "San Joaquin," began in the previous year under contract with the Ellicott Machine Company, of Baltimore, Md., dated January 22, 1912, was continued during the past year. The material for these dredges was assembled at Baltimore, Md., shipped to Pittsburg, Cal., and erected at the latter place. The dredges were practically completed at the close of the fiscal year, but they had not been given the thirty days' trial required by the contract. This trial is being held in abeyance pending the completion by the contractor of some minor changes found necessary during the preliminary trial of the dredges. It is anticipated that these changes will be completed in August, 1913, and that the thirty days' trial may immediately follow.

Proposals for furnishing and delivering at Rio Vista, Cal., 20-inch diameter steel and wooden discharge pipe and two welded steel elbows for the two dredges were invited by advertisement dated August 8, 1912, and opened on September 9, 1912. Proposals were invited for three lots of pipe. Lot No. 1 consisted of 2,408 linear feet of welded steel pipe and two welded steel 90° elbows. The proposal of George J. Henry, Jr., of San Francisco, Cal., was accepted for lot No. 1, and a contract therefor was entered into with him on October 16, 1912. This contract was completed during the year.

Lot No. 2 consisted of 2,500 linear feet of riveted steel pipe. The proposal of the Schaw-Batcher Company Pipe Works, of Sacramento, Cal., was accepted for lot No. 2, and a contract therefor was entered into with that company on October 18, 1912. This contract was completed during the year.

Lot No. 3 consisted of 2,500 linear feet of wooden stave pipe. The proposal of the Pacific Tank and Pipe Company of San Francisco, Cal., was accepted for lot No. 3, and a contract therefor was entered into with that company in October, 1912. This contract was completed during the year. It having been found that more wooden stave pipe could be used to advantage, 2,516 additional linear feet were purchased under oral agreement of the Pacific Tank and Pipe Company, at the price named in their contract for the 2,500 linear feet comprising lot No. 3, above referred to. The delivery of the additional 2,516 feet of pipe was completed during the past year.

Proposals for furnishing and delivering at Rio Vista, Cal., 68 pontoons for the pipe lines of the two suction dredges were invited by advertisement dated October 8, 1912, and opened on November 7, 1912. The proposal of Johnson and Lanteri, of Pittsburg, Cal., was accepted, and a contract for the pontoons entered into November 29, 1912. This contract was completed during the year.

In addition to the foregoing the dredges were partially equipped during the year with all the necessary furnishings. The latter were purchased after inviting proposals by circulars and by oral agreement.

Motor dredge tender "Rio Vista." On November 26, 1912, proposals were invited for the construction of motor dredge tender "Rio Vista," for use in connection with dredges "Sacramento" and "San Joaquin." The proposals were opened on December 16, 1912. The proposal of Nunes Bros., of Sacramento, Cal., for constructing the hull of the dredge tender was accepted, and a contract therefor was entered into on December 31, 1912. This contract was nearing completion at the end of the year.

The proposal of the Atlas Gas Engine Company, of Oakland, Cal., for furnishing and installing the engines and accessories in the hull of the dredge tender was accepted, and a contract therefor was entered into December 31, 1912. This contract was nearing completion at the end of the year.

Storehouse and mooring grounds at Rio Vista. For carrying on the operations under this project a storehouse is necessary. In former years United States snagboat "Seizer" and other floating plant belonging to the Sacramento River work were moored, when out of commission, along the water front at Sacramento. This water front having become crowded with river craft, it became necessary to moor the government plant referred to, when out of commission, elsewhere. Rio Vista was selected as the most suitable location for this purpose. In addition to being convenient for all the Sacramento River work, it is also centrally located for the San Joaquin and Mokelumne River work. To meet the requirements of all these works a storehouse and wharf was constructed and mooring grounds prepared by hired labor at Rio Vista during the past year, the cost being defrayed from the appropriations properly chargeable therewith. This wharf is 120 feet long by 44 feet wide, including the space occupied by the storehouse, which latter is 56 feet long by 26 feet wide.

Lands. Title to or easements over approximately 2,260½ acres of land were acquired during the past year under the requirement of the act of congress of June 25, 1910, that rights of way needed for levees and spoil banks for this work should be furnished the United States free of cost.

Surveys of lands. Several surveys were made during the year of the lands required for the work and to lay out the lines of the work to be done under the project.

The expenditures during the year from the appropriation made by congress were $268,276.18, and from the funds contributed by the State of California $17,490.93, or a total of $285,767.11. These expenditures were as follows:

For	From appropriation by congress	From appropriation by State of California	Total
Construction and equipment of suction dredges "Sacramento" and "San Joaquin," including pontoons and pipe for pipe lines	$261,847 28	$13.720 00	$275,567 28
Construction and equipment of dredge tender "Rio Vista"	2,699 76	3,150 91	5,850 67
Storehouse and wharf at Rio Vista, Cal.	1,716 96	582 49	2,299 45
Survey of lands	2,012 18	37 53	2,049 71
Totals	$268,276 18	$17,490 93	$285,767 11

The work proposed during the fiscal year ending June 30, 1914, is as follows:

Completion of and equipment for suction dredges "Sacramento" and "San Joaquin"	$15,000 00
Completion of and equipment for dredge tender "Rio Vista"	5,500 00
Completion of storehouse and wharf at Rio Vista, Cal.	800 00
Operating two suction dredging plants August 1, 1913, to June 30, 1914, eleven months at $7,500 each per month	165,000 00
Total	$186,300 00

Estimate of Additional Funds Required.

Amount that can be profitably expended in fiscal year ending June 30, 1915, for works of improvement		[1]$200,000 00
Appropriations by congress, act of June 25, 1910		400,000 00
Appropriations by State of California:		
Act of state legislature of March 1, 1909	[2]$400,000 00	
Act of state legislature of June 7, 1913	[3]200,000 00	600,000 00
Total		$1,000,000 00

[1]Exclusive of the balance unexpended July 1, 1913.

[2]Deposited in the treasury of the United States by the State of California on July 1, 1911.

[3]Conditional. See summary of this report for the provisions of the act of the state legislature of June 7, 1913.

Abstract of contracts in force.

Name of contractor	For	Price	Date of approval	Date of beginning work	Date of expiration of work
			1912	1912	1913
Ellicott Machine Co., Baltimore, Md.	Two 20-inch suction dredges.	$176,800 each	Feb. 28	Apr. 1	Apr. 13
Geo. J. Henry, Jr., San Francisco, Cal.	2,408 linear feet welded steel pipe, 21 inches outside diameter.	$4.70 per foot	Nov. 12	Nov. 30	Mar. 14
	2 welded steel 90 degree elbows.	$90.00 each.			
Pacific Pipe and Tank Co., San Francisco, Cal.	2,500 linear feet wooden stave pipe, 20 inches inside diameter.	80.9 cents per foot.	Nov. 19	Dec. 13	Mar. 12
The Schaw-Batcher Co., Pipe Works, Sacramento, Cal.	2,500 linear feet riveted steel pipe, 20 inches inside diameter.	$1.45 per foot	Nov. 12	Nov. 30	Mar. 14
			1913	1913	
Johnson & Lanteri, Pittsburg, Cal.	68 pontoons	$19,788.50 for all	Jan. 24	Feb. 26	June 25
Nunes Bros., Sacramento, Cal.	Hull for dredge tender "Rio Vista."	$4,625	Jan. 23	Feb. 16	July 6
Atlas Gas Engine Co., Oakland, Cal.	Engine for dredge tender "Rio Vista."	$4,575	Jan. 23	Feb. 16	July 6 1914
Pacific States Refineries, San Francisco, Cal.	Machinery oil	8¾¢ gallon	[1]	May 11	May 1
	Engine oil	20¾¢ gallon			
	Engine oil	16¾¢ gallon			
	Cylinder oil	34¢ gallon			
	Dynamo and motor oil	24½¢ gallon			
	Ice machine oil	22½¢ gallon			
	Kerosene	15¢ gallon			
	Cable lubricant	30¢ gallon			
	Cable coating	6¢ pound			
	Cup grease	5¼¢ pound			

[1]Emergency contract.

Respectfully submitted.

(Signed) THOS. H. REES,
Lieut. Col., Corps of Engineers.

(Signed) C. H. MCKINSTRY,
Lieut. Col., Corps of Engineers.

(Signed) S. A. CHENEY,
Major, Corps of Engineers.

The Chief of Engineers, United States Army.

ANNUAL REPORT OF THE CALIFORNIA DEBRIS COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1914.

CALIFORNIA DEBRIS COMMISSION,
SAN FRANCISCO, CAL., July 1, 1914.

SIR: The California Debris Commission submits the following annual report for the fiscal year ending June 30, 1914:

REGULATION OF HYDRAULIC MINING AND PLANS FOR IMPROVEMENT AND PROTECTION OF RIVERS AND CONTROL OF FLOOD WATERS AND MINE DEBRIS.

Regulation of hydraulic mining in the drainage areas of the Sacramento and San Joaquin River system. During the fiscal year the Commission received two applications for permits to mine by the hydraulic process under the provisions of the act of congress approved March 1, 1893, as amended by the act approved February 27, 1907.

During the same period one permit to mine by the hydraulic process was granted, the applicant having constructed the necessary dam to impound the debris resulting from the mining operations so as to prevent it from reaching the navigable streams. As in former years, numerous personal inspections were made of the hydraulic mining region and of mines and their works for impounding debris.

Plans for improvement and protection of rivers and control of flood waters and mine debris. Under the provisions of the act of congress approved March 1, 1893, the Commission is required to mature and adopt such plans from examinations and surveys as may be deemed necessary to improve the navigability of all the streams comprising the Sacramento and San Joaquin River systems, deepen their channels, and protect their banks, such plans to be matured with the view of making the same effective as against the encroachment of and damage from debris resulting from mining operations, natural erosion, floods, and other causes. Several surveys were made during the past year in the Sacramento and San Joaquin valleys to obtain data needed in formulating plans for these purposes, and many meetings were held at which the numerous problems involved were considered and discussed with individuals, representatives of the State of California and corporations interested in transportation, reclamation, irrigation, flood control, and mining.

The expenditures during the fiscal year ending June 30, 1914, for regulating hydraulic mining and making examinations and surveys for improvement of navigation, control and disposition of mine debris, and control of flood waters were as follows:

Surveys of portions of San Joaquin River	$10,899 30
Survey of portion of Mokelumne River	1,199 63
Regulating hydraulic mining, examinations, surveys, plans for control and disposition of mine debris and control of flood waters in the drainage areas of the Sacramento and San Joaquin river systems	2,095 80
Total	$14,194 73

STORAGE OF MINE DEBRIS IN YUBA RIVER, CAL.

The operations during the past year under the general project for storing mine debris in Yuba River, under appropriations made by congress and the legislature of the State of California, have been as follows:

Training walls. The work of constructing the gravel embankments (referred to at pages 2929–2930 of the annual report for 1911) by means of gold dredges to confine and control the flow of Yuba River in the vicinity of Daguerre Point, about ten miles above Marysville, under agreement with W. P. Hammon and associates, was continued. These embankments are being built for the United States and State of California in exchange for the right to extract gold from certain lands of the United States.

In spite of the low flow last year less difficulty than usual was experienced in navigating up to Sacramento, and no dredging was necessary immediately below the city to maintain the seven-foot channel.

The Weather Bureau gauge at Sacramento showed the lowest reading (2.5 feet) that has been noted for over forty years. This was not entirely due to the low discharge, for lower discharges have occurred in this period, but rather to the fact that the river bed is working down to the condition obtaining before the days of unrestricted hydraulic mining. The following table of average low-water readings at Sacramento, by five-year periods, compiled from such data as are available, will serve to indicate the effect of mine debris on the river stages at this point.

Average low water at Sacramento for five-year periods, 1849-1913.

Average gauge reading:	
1849-1853, five observed years	0.6 feet
1854-1858, five observed years	1.2 feet
1859-1863, three observed years	2.2 feet
1863-1873, no records.	
1874-1878, five observed years	5.5 feet
1879-1883, five observed years	6.5 feet
1884-1888, five observed years	7.3 feet
1889-1893, four observed years	7.8 feet
1894-1898, five observed years	8.0 feet
1899-1903, five observed years	7.2 feet
1904-1908, five observed years	6.8 feet
1909-1913, five observed years	4.7 feet

The records indicate that the water reached zero on this gauge in 1849 and again in 1856. The peak of the debris effect appears to have been reached in 1896 at a reading of 8.5, although in 1890 a reading of 9.3 occurred. Over 2 feet of tide was noted during low-water stages last summer.

Inlet wall at Daguerre Point cut. Proposals for raising the inlet wall and facing it with timber (see last annual report, page 3172) were invited by advertisement dated May 20, 1914. The proposals are to be opened on July 1, 1914.

The expenditures during the year were as follows:

For additional concrete placed in the apron of the inlet wall, and for plans and specifications for raising the inlet wall, at Daguerre Point cut	$630 08
Amount (one half) paid by the State of California	315 04
Balance (one half) paid by the United States	315 04

APPROPRIATIONS BY CONGRESS.

June 3, 1896	$250,000 00
June 13, 1902	150,000 00
Total	$400,000 00
Received from sales	28,279 48
Total	$428,279 48

In addition to the appropriations made by congress, the State of California has appropriated a total of $400,000 for the Yuba River project.

GENERAL PROJECT FOR CONTROL OF DEBRIS AND FLOODS IN THE SACRAMENTO AND FEATHER RIVERS.

The scope of this project is set forth under the above heading in the summary of this report.

The operations during the past fiscal year have been as follows:

Constructing and equipping dredging plants. The construction of the two 20-inch suction dredges "Sacramento" and "San Joaquin," under contract with the Ellicott Machine Company, of Baltimore, Md., dated January 22, 1912, was completed during the past year, as was also motor dredge tender "Rio Vista," under contracts with Nunes Bros. and the Atlas Gas Engine Company, dated December 31, 1912. The expenditures during the year on account of original construction and original equipment of this plant were $29,667.21.

This completed that part of the general project (report printed in the annual report of the Chief of Engineers for 1907, pages 2262–2269) which contemplated the construction of two hydraulic dredges.

Increasing the flood carrying capacity of Sacramento River below Cache Slough. Upon the completion of the two dredges and other plant above referred to, operations were begun on the work of channel enlargement necessary to increase the flood

carrying capacity of the Sacramento River below Cache Slough from 165,000 second feet to 600,000 second feet, as indicated on map (Sheet E) printed with House Document No. 81, sixty-second congress, first session. This involves the dredging of approximately 148,600,000 cubic yards of material (House Doc. No. 81, sixty-second congress, first session, page 21). Dredging operations were begun in Sacramento River a short distance above Collinsville in August, 1913, with suction dredges "San Joaquin" and "Sacramento," each with a crew of approximately 40 men. Up to June 30, 1914, dredge "San Joaquin" removed 1,823,049 cubic yards of material from the river, at a total cost of $83,278.07, or 4.568 cents per cubic yard. This material was deposited on the west bank of the river above the flood plane. Up to June 30, 1914, dredge "Sacramento" removed 1,549,996 cubic yards of material from the river, at a total cost of $84,758.40 or 5.4683 cents per cubic yard. Practically all the material dredged by the "Sacramento" was deposited on Sherman Island, where it was used in levee construction on the lower end of the island, and at Baker's Point opposite Toland's Landing. At page 39 of House Document No. 81, above referred to, this point was referred to as the one where the channel of the river is the most contracted.

Of the 1,549,996 cubic yards of material dredged from the flood channel of the river by dredge "Sacramento" the past year 1,347,383 cubic yards were placed in the levee at the lower end of Sherman Island. This levee is one mile in length. It is approximately 13 feet in height, 10 feet wide at the crest and 200 feet at the base. Work on this levee was begun in August, 1913, and completed in May, 1914. The cost of this levee work up to June 30, 1914, was $22,233.27.

Of the 1,549,996 cubic yards of material dredged by dredge "Sacramento" the past year, 202,613 cubic yards were placed in the levee on Sherman Island at Baker's Point, opposite Toland's Landing. This levee is to be approximately 6,100 feet in length, 20 feet high, 10 feet wide at the crest and 400 feet at the base. Work on this levee was begun in May, 1914. The cost of this levee work up to June 30, 1914, was $5,904.55.

The dredging and levees above referred to are in furtherance of the plan to increase the width and depth of the river between Collinsville and Cache Slough to full flood section, in acordance with paragraph 72, page 21 of the House Document No. 81, above referred to.

The total cost of all the work during the year was as follows:

Amount expended during the year	$222,072 70
Outstanding liabilities at end of year	3,768 80
Total cost	$225,841 50

The expenditures during the year from the appropriation made by congress were $1.67, and from the funds contributed by the State of California $222,071.03, or a total of $222,072.70. These expenditures were as follows:

For	From appropriation by congress	From appropriation by State of California	Total
Completion and equipment of suction dredge "Sacramento," including pontoons and pipe for pipe lines	$1 67	$13,108 88	$13,110 55
Completion and equipment of suction dredge "San Joaquin," including pontoons and pipe for pipe lines		11,866 83	11,866 83
Completion and equipment of dredge tender "Rio Vista"		4,110 93	4,110 93
Completion of storehouse and wharf at Rio Vista, Cal.		578 90	578 90
Dredging, by suction dredge "Sacramento"		84,214 17	84,214 17
Dredging by suction dredge "San Joaquin"		82,338 38	82,338 38
Construction of levee on lower Sherman Island		20,693 27	20,693 27
Construction of levee at Baker's Point, Sherman Island		5,159 67	5,159 67
Totals	$1 67	$222,071 03	$222,072 70

Appropriations by congress.

Act of June 25, 1910 ..... $400,000 00

Appropriations by State of California.

Appropriated by act of state legislature of March 1, 1909, and deposited in treasury of United States by the State of California on July 1, 1911 ..... $400,000 00
Received from treasury department settlements and miscellaneous collections 764 85

Total, state fund $400,764 85

Appropriated by act of state legislature of June 7, 1913 (conditional; see summary of this report for the provisions of this state appropriation) $200,000 00

Abstract of contracts in force.

Name of contractor	For	Price	Date of approval	Date of beginning work	Date of expiration
			1913	1913	1913
Nunes Bros., Sacramento, Cal.	Hull for dredge tender "Rio Vista."	$4,625	Jan. 23	Feb. 16	July 6
Atlas Gas Engine Co., Oakland, Cal.	Engine for dredge tender "Rio Vista."	$4,575	Jan. 23	Feb. 16	July 6 1914
Pacific States Refineries, San Francisco, Cal.	Machinery oil	8¾¢ per gallon	[1]	May 11	May 1
	Engine oil	20¾¢ per gallon			
	Engine oil	16¼¢ per gallon			
	Cylinder oil	34¢ per gallon			
	Dynamo and motor oil	24½¢ per gallon			
	Ice machine oil	22½¢ per gallon			
	Kerosene	15¢ per gallon			
	Cable lubricant	30¢ per gallon			
	Cable coating	6¢ per pound			
	Cup grease	5¼¢ per pound			
					1915
Standard Oil Co., San Francisco, Cal.	Fuel oil f.o.b. dredges "Sacramento" and "San Joaquin."	$1.05 per barrel	[1]	Aug. 10	Aug. 10
	Fuel oil at Pittsburg, Cal.	85¢ per barrel			
					1914
	Engine distillate at Pittsburg, Cal.	6½¢ per gallon	----------	----------	Aug. 10

[1]Emergency contract.

Respectfully submitted.

(Signed) THOS. H. REES,
Lieut. Col. Corps of Engineers.

(Signed) R. R. RAYMOND,
Major, Corps of Engineers.

(Signed) S. A. CHENEY,
Major, Corps of Engineers.

The Chief of Engineers, United States Army.

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RIVER WORK.

Among the duties prescribed for the Department of Engineering by the statutes, the law creating it recites that:

All matters of drainage, and improving and rectifying river channels and other work on any river or slough flowing into San Francisco Bay, San Pablo Bay, and Suisun Bay, and also the tide waters flowing into said bays, shall be placed under the management and control of the Department of Engineering whenever the law provides therefor. The Department of Engineering shall have charge of all expenditures, unless otherwise provided by law, for all public works relating to general river and harbor improvements, including reclamation and drainage of lands. It may purchase, construct, and operate one or more dredges, or any other needed appliances to promote or properly carry out the work of the department. The State Engineer, in the name of the State of California, may obtain or condemn any right of way necessary for any construction herein named, and shall proceed, if necessary, to condemn under the terms of the Code of Civil Procedure relating to such proceedings. The department shall have the power to employ such additional help for the performance of the work of this section as the Advisory Board shall order, and all money now appropriated to the Board of Public Works and remaining unexpended, shall be used for the purposes intended by the law, by the Department of Engineering, and the State Controller shall transfer said funds to the credit of the Department of Engineering. Wherever under any statutes of this State any duty or obligation, the performance of which is imposed upon the Commissioner of Public Works, or the auditing board to the Commissioner of Public Works, the same shall be assumed and the performance of the same shall devolve upon the Department of Engineering.

By virtue of the foregoing provision of the law, the Department of Engineering succeeded to the duties of the Commissioner of Public Works, who had formerly had charge of all state work in the interest of navigation on the inland waters of California.

The first appropriation for this purpose was made by the legislature in 1897, when $300,000 was appropriated for the purpose of "rectifying and improving the channels of Sacramento, San Joaquin and Feather rivers and such other channels of the state as may be determined and to improve the navigability of said streams." A study of river conditions and a system of channel regulation was then inaugurated.

Further appropriations were made from time to time and continued after the Department of Engineering was created in 1907 and took over the work of the Commissioner of Public Works.

In the opening chapter of this report the functions of the consulting board to the Department of Engineering are stated. All applications for state aid in works affecting the rivers is referred to this board for consideration.

Wherever proposed work in the interests of navigation and the control and maintenance of stable conditions of the rivers involves also direct benefits or protection to the lands seeking to have the work done, it has been the policy of the consulting board to recommend the work done by the state, provided the property interests to be directly benefited shall pay one half, or more than half, of the cost of the work.

In all of the original work undertaken during the past two years this rule has been adhered to excepting where stated in the description of the same.

No floods have occurred in the Sacramento watershed since 1909, although each spring rise has furnished sufficient water to flow out through the breaks and over low banks without levees. Therefore, no new crevasses have occurred in the levees, and low water navigation in the Sacramento River has been unusually free from serious interference.

In many places, however, serious caving of the banks has developed. Several applications have been made for state aid in arresting the bank erosions. Where it was considered that danger existed of the river breaking through the bank and making crevasses or new channels, and the property owners were willing to pay at least half of the cost for protection work, it has been afforded. Many applications for assistance have been made, however, where the washing away of the land is a serious loss to the land owner, but does not appear to threaten the integrity of the stream or endanger navigation. In such cases, the law not permitting the expenditure of state funds, the applications were regretfully rejected.

SACRAMENTO RIVER.

Crouch Landing.—The bank at this point has been washing away for several years until the shore line has moved 300 or 400 feet inland. Several thousand dollars have been expended by the government, the state and the property owners in works to arrest it, but the last high water washed away all that had been constructed.

A survey was made for a cut-off across the arc of the bend, but the cost of the cut would be so great and its untility being doubtful, it was abandoned. It is believed that bank protection, if well done, will most effectually remedy the evils, and for this purpose plans have been prepared to place concrete protection along 1,500 to 1,800 feet of bank.

For this purpose the advisory board has authorized the expenditure of $15,000 provided the property owners shall pay one half. Owing to

the lateness of the season and likelihood of high water coming before it can be finished, which would probably destroy all that had been laid, the work will not be undertaken until next summer.

Meridian.—The banks here are caving badly and present a serious condition. Should erosion continue much farther there is danger of a break being made into Sutter Basin with attendant great loss of property and injury to navigation. There are many interests involved and at the present writing they have not been able to unite so as to pledge their share of the expense of protective works.

Grimes.—Extensive bank protection had been constructed at this landing some years ago. Some of it had become damaged and other work was required to further protect the bank. Property owners deposited the required funds to cover half the cost of the work, which was completed in the early summer.

Collins Eddy.—Conditions at this point have been growing worse every year for some time. The eddy is at the apex of a very sharp bend which is becoming more accentuated each season, until now it is very difficult for a steamer going up with a heavy tow to make the turn.

The erosion has taken nearly half of the levee at one point, and weakened it so that but little more caving will destroy it. The land slopes very rapidly from here toward Sutter Basin and should a breach occur, which seems imminent at the next high water, a serious condition would result. Property would be destroyed, land damaged, and the division of the stream would injure the main river below, entailing a large expense to close the break.

The United States engineers and the Department of Engineering agreed upon a type of work to be constructed and the division of expense, whereupon the property owners agreed to contribute a share to the cost.

The type of work designed is a pile and brush bulkhead about 1,000 feet in length, to cost $8,000. The federal government agreed to furnish and drive the piles, and some other work to the extent of $2,000. The property owners deposited $3,000 with the State Engineer. The work will begin at once and should be completed before winter rains set in.

Tisdale Weir.—The channel approach to the weir had become filled with growing brush, which collected a large amount of drift. A great number of large logs had lodged under and against the county highway bridge just above the weir.

The accumulation of drift had caused holes to be washed at the upstream side of the structure. The surfacing of the weir crest is badly cracked and scales off in large areas.

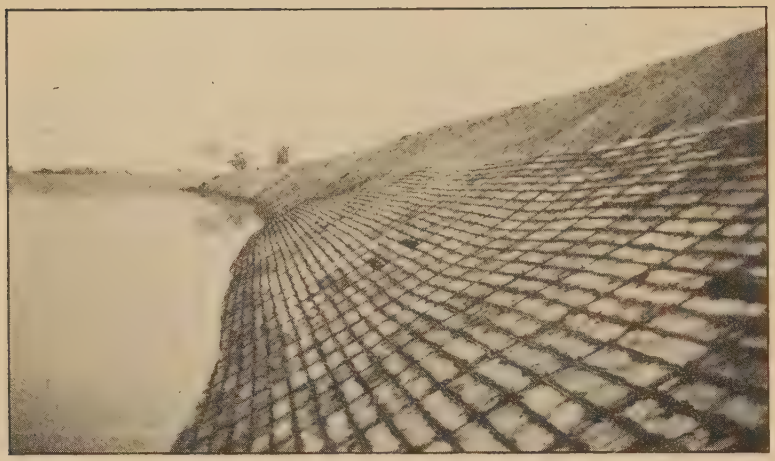


Plate XXI—A. Bank Protection—Articulated Concrete Revetment.

B. River Work, Construction Camp.

During the past summer, the channel was cleared of brush; the drifts cut up and burned; the holes filled with hard material and the broken surface of the concrete patched, placing the weir in good condition for another season.

Knights Landing.—Pile bulkheads put in here several years ago have become dilapidated. The advisory board authorized repairs to be made, which will be done with the equipment used at Collins Eddy.

Elkhorn Weir.—The channel way from the weir, as well as the space in front of the weir becomes overgrown with brush, which interferes with its functions and requires to be cleared periodically. Much clearing is done in cutting brush for bank protection along the river, but in 1912 and 1913 there was so little brush used that it became necessary in 1913 to clear the waterway, which was done at a cost of $1,400.

Rock Point.—This is a place that has always given much concern, being situated in a position where it is attacked by the current of Sacramento River reinforced by the American, and with the streets and buildings of the town of Washington in the line of destruction should a break occur presents a serious condition.

It is estimated that adequate protection will cost $15,000. The department suggests that the property owners should pay two thirds and the state one third of the cost. At this writing the people concerned have not reached an agreement.

Edwards Break.—This place is a short distance below the city of Sacramento. A break occurred here in 1904 which entailed a loss of probably a million of dollars. The flood waters of the river poured through the break for many weeks inundating the whole Sacramento basin to the Mokelumne River, causing that stream to overflow its contiguous territory. The waters backed into the city of Sacramento, requiring constant diligence on the part of the city to prevent a break in the Y street levee. The break was not closed until several months had elapsed, and it is said the cost to some of the lands affected exceeded $100 an acre, besides much damage and loss of crops. Conditions in the vicinity of the Edwards break have been unsatisfactory for some years. Several thousand lineal feet of brush mattress have been laid to arrest the erosion of the banks and levees.

While these mattresses afford an excellent protection, their life is short. The brush soon decays and when the water recedes in summer the brush becomes dry and is easily burned. Much of that laid in the vicinity under discussion has been destroyed by fire. Much of the land in the city limits which was only farms at the time of the break ten years ago has been annexed to the city and is closely built up with urban homes with improved streets.

Conditions along the levee were becoming alarming, and in view of the importance of the territory threatened it was considered that a more permanent type of work should be introduced.

Reclamation District No. 535, which lies along the river front and extends back to high land, presented a plan for revetting the face of the levee with a flexible concrete pavement. The cost of the work was estimated at $75,000, which the district officers declare was beyond the resources of the district and asked for assistance from the state.

The advisory board authorized the cooperative expenditure of $75,000 and work is now in progress, and should be completed before high water arrives.

Freeport.—Bank erosion here has been exceedingly troublesome. Negotiations were pending at the time of the last report for cooperative action to place protecting work, but without avail. A county road runs on top of the levee, and during 1913 the erosion progressed so far as to destroy the road in places, and threatened to continue through the levee. The department cooperated with the county of Sacramento and some of the property owners in applying protection to the worst places. The state's share of the cost of this work was $1,000.

Brannan Island.—Some old work along the Sacramento shore of this island had become badly dilapidated. Repairs to this and some new mattress work, as well as replanting willows on some old mattress was executed in cooperation with the land owners to the extent of more than $5,000.

Sherman Island.—Most of the former work on the shore of this island has stood well. Three-mile Slough is a branch of Sacramento River between Sherman and Brannan islands, emptying into the San Joaquin River opposite Jersey Island. About half a mile from the head the slough turns abruptly to the left, and the swirling waters have washed out a deep pool which has a tendency to constantly work inland.

Several years ago a bulkhead of piles and brush was constructed here to stop the erosion. The depth of water is more than fifty feet and the bottom is hardpan so that piles can not be driven with sufficient penetration to make them secure. Owing to the swift and whirling current passing steamers and barges are sometimes thrown against the bulkhead with great force, breaking the piles or loosening them. For this reason annual repairs are necessary. During the last two years repairs have been made in cooperation with the trustees of Reclamation District No. 341.

Sacramento City.—Along the Merkeley levee below the city of Sacramento the state some years ago revetted a considerable length of the levee. Later this territory was annexed to the city and extensive shore improvements were undertaken. The rise of the river last spring came

before the work was completed and some of it was destroyed. The department cooperated with the city in repairing the damaged revetment to the extent of $5,000 of state funds.

FEATHER RIVER.

It was stated in a preceding chapter that Feather River is subject to a constant influx of sand from the mining debris lodged in the channel and basins of Yuba River, and that fifteen years ago the federal authorities had ceased to do any snagging or other work in aid of navigation upon this stream. As a consequence of these conditions the channel had become full of snags and greatly choked by shifting sand bars so that steamboats had ceased trying to reach Marysville excepting during high water.

The city of Marysville enjoyed "terminal rates" on freight from outside the state owing to those rates having been established before the steamers had withdrawn from the Feather River. In fear that the Interstate Commerce Commission would cancel these favorable rates, the civic bodies of Marysville petitioned the Department of Engineering to endeavor to restore navigable conditions on the river.

Surveys were made and the advisory board authorized the expenditure of $7,000 for snagging and other work, and $10,500 to make a cutoff across Nelson bend, provided the adjoining property owners should cooperate in the latter work.

During the summer of 1913 the department removed and destroyed more than 1,000 snags from the channel of the river, and a system of training walls was inaugurated to produce deeper water at the shoals.

The quantity of sand in Feather River below the mouth of the Yuba is so great that when the flood flow falls below the transporting velocity, innumerable sand bars form.

Where the current follows along the side of the channel, particularly in the concave side of a curve, there is usually a good depth, even during the low summer flow, but where the current crosses to the opposite side the water spreads in a broad, shallow sheet across the intervening bar.

It is requisite that no structures placed in the channel shall offer any obstruction to the free flow of flood waters, therefore training works must be low—no higher than the surface of low water.

The method adopted for causing the water to increase in depth at the "crossings" is to construct wattles made of green brush woven between stakes driven down to the water's surface. The wattles are constructed in lines approximately parallel with the axis of the river but diagonally with the crossing current, so as to confine some of the spreading water to narrower limits. They have proven quite effective in causing the water to quickly scour channels deep enough for light draft boats to

negotiate the crossings from one pool to another. While they are not permanent in character and are liable to be washed out with the next high water, that is not of much moment, since the shifting bars are likely to transfer the place of need to another location the next season. They are cheaply made, serve their purpose for the season and do not obstruct the flood flow nor interfere with boats passing over them as soon as they are sufficiently submerged.

When the work began on Feather River the city of Marysville donated equipment worth about $1,500 and with the state funds allotted, several thousand feet of these little "training walls" were constructed. The effect of the work done on the river in removing snags, including two dams in a cut-off across Eliza bend, and deepening crossings was to enable a steamer to make weekly trips to Marysville until June, 1913.

A contract was let to the owners of land adjoining Nelson bend to dredge a cut across the bend for the sum of $10,500. The dredged material was used in constructing a strong levee along the bank of the cut. The cost to the contractor was considerably more than $21,000, and the cut eliminates a very bad turn in the bend.

During the summer just passed, some of the training walls were repaired or restored and others constructed, snags were removed and the land along Nelson bend cut-off cleared for an additional width of 100 feet.

The work in the river it is confidently believed is having a beneficial effect, as boats were able to go several miles up the stream and bring out cargoes of beans, etc., during the fall and in November a steamer took a load of goods to Marysville. This had not been possible before in a quarter of a century.

It is expected to continue the work next year, and it is hoped to be able to demonstrate that navigation can be maintained in the Feather River at small cost.

SAN JOAQUIN RIVER.

No work has been done on this stream below Stockton during the period just closed, though a small amount is provided for.

In 1913 application was made for the department to undertake extensive work in rectifying the channel of Middle River. The legislature had just enacted a law including flood control and reclamation on the San Joaquin with the Sacramento Valley project.

It was believed that no work should be executed at public expense in the delta channels unless such work would be in harmony with the ultimate control of floods in those channels.

A survey of Middle River and of Old River was made from their origin to the crossing of the Santa Fe Railroad. It was found that both channels are in fact navigable part of the year excepting for fixed

highway bridges crossing them. It was concluded that more extensive surveys than was then advisable would be required to determine the extent of rectifying that might be done, so the application was temporarily laid aside.

The San Joaquin River is a sluggish stream carrying a great deal of sand, any breaks occurring in the banks to cause a division of the waters is sure to cause shoals and sand bars to form and impede navigation.

The amount of water traffic above Stockton is limited, and does not warrant a great expenditure to maintain navigable conditions, but should new channels be allowed to form they would draw off so much of the water that the navigable depth below Stockton would be reduced to such a degree as to seriously interfere with navigation to that city.

Until the investigations now being made shall develop a complete plan for flood control, reclamation and navigation throughout the system, the policy of the Department of Engineering should be to maintain conditions as they are; and with that object in view, the activities of the state along the San Joaquin River during the last two years has been confined to assisting the owners of property along the river to maintain their levees, and to install bank protection where dangerous conditions obtain.

District No. 544.—At the time of the report two years ago work was just being completed at the divergence of Old River from the San Joaquin, to arrest erosion of the levees that threatened a serious break. This work consisted of a flexible brush mattress and was constructed in cooperation with the district, the state paying half of the cost.

During 1913 slight repairs were made to the mattress and green stakes driven where the mattress brush had failed to grow. At this time additional repairs are being made to the work and a new mattress laid; the district paying one half the cost.

District No. 17.—A dangerous erosion of the bank and levee between the Southern Pacific railroad bridge and the head of Old River existed, and a mattress 1,250 feet long had just been placed at the close of the previous report. Repairs and replanting of growing willows was done in 1913 and at this writing the mattress is being repaired.

Paradise Bend.—The work in progress at this point two years ago was completed but the extension of the caving has necessitated new work and the department is now placing a mattress about 1,600 feet in length, the land owners cooperating in the expense.

Banta Reclamation District.—A short distance above the Western Pacific railroad bridge, a threatened break in the levee developed in 1914. A distance of about 1,300 feet being in need of protection, preparations were made to lay a mattress upon it. Work will begin very soon, the property owners to participate in the cost.

Smith's Canal.—At the entrance to the river of a short slough known by the foregoing name some pile protection work constructed several years ago has become badly dilapidated and the wave wash from passing steamers is eroding the levee badly. A protection 350 or 400 feet in length is required, and there being a large quantity of brickbats available at a nearby yard, it is proposed to pave the slope with loose brick as being a cheap and efficient protection.

The advisory board authorized the expenditure by the state of $587.

CALAVERAS RIVER.

The Calaveras River divides into two branches soon after debouching from the hills. One branch runs southwesterly and becomes known as Mormon Slough. It passes through the city of Stockton, joining San Joaquin River a mile below the city.

The other channel retaining the name of Calaveras runs more westerly, passes about two miles north of Stockton and enters the San Joaquin some three miles below the mouth of the Mormon Slough branch.

Floods in Mormon Slough inundated portions of Stockton and caused much inconvenience and damage, and a few years ago the government constructed a canal diverting Mormon Slough into Calaveras River three or four miles east of Stockton. Above the junction of the canal and river the levees along the latter are very weak or entirely lacking and the access of flood waters from Mormon Slough causes the Calaveras to flow over the banks or break the levees above.

The escaping water flows southwestward over the intervening plains until intercepted by the levees along the Calaveras and San Joaquin near their confluence. In its course it injures roads and interrupts and endangers travel thereon. State property at the farm of the Stockton State Hospital suffers great injury from these flood waters. In 1911 the waters accumulated against the levees on the farm and destroyed several acres of an orchard.

In 1912 the state in cooperation with the county of San Joaquin undertook to build a levee from the junction of the diverting canal upstream along the west bank of the Calaveras for about 4,000 feet, shutting off the worst overflow. The work was delayed, and was not completed before high water in the winter of 1913. The high water made two breaches in the levee.

In the summer of 1914 in cooperation with the county the state repaired the levee, raised and strengthened it, and cleared the channel of Calaveras River, so that conditions are now greatly improved at that point.

The foregoing constitutes the history of construction accomplished or undertaken since the last report in the navigable streams of the state

under the provisions of the act appropriating moneys for the "rectification and improvement of Sacramento, San Joaquin, and Feather rivers and the improvement of the navigability of said streams."

Method of Work.—Nearly all of the river work executed by the department is done by "force account." A camp is established at the site of each piece of work, and the men boarded at the camp. Care is exercised to keep the commissary up to a high standard, all foodstuffs being of the best quality and of good variety. Kitchen arrangements are complete and convenient, and cooking is required to be well done and cleanly. Kitchen and dining quarters are well screened and all garbage is taken care of in a sanitary manner. Large ice chests are provided for all perishable foods. Where the domestic water supply is not above suspicion all drinking water is either boiled or filtered or both.

Tents are provided for sleeping quarters restricting their occupancy to two persons to each ordinary sized tent. The men are required to furnish their own blankets, but single bunks are given for which clean straw is provided and changed every week or whenever a bunk is vacated. Bunks are frequently washed with germicide solution.

Bathing facilities are provided, the tubs furnished with hot and cold water. The water for bathing is heated by the same boiler furnishing water for washing clothes. Plenty of soap is furnished to each man. A large assembly tent is provided with a stove where men who get wet may dry their clothes before going to their individual quarters. Most of the small tents are furnished with heating stoves. In short every effort is made to maintain the camp in a comfortable and healthful condition.

The river division possesses one large working barge, one small barge, a pile driver, a kitchen houseboat, one towing launch, one fast dispatch launch, five rowboats and two portable skiff engines capable of driving the row boats five to seven miles an hour. When work is required at more than one place at a time it becomes necessary to rent barges. For that reason the department should have at least one more working barge and one or two small barges for hauling brush and other materials.

In addition to the expenditures for construction detailed above, the fund provided by the appropriation act quoted, has been used for other purposes directly connected with improving the navigability of the streams as follows:

MISCELLANEOUS WORK.

Enlarging the Sacramento.—In discussing flood control in a previous chapter herein, it was shown that the appropriation by congress of $400,000 for beginning the work of enlarging the mouth of the Sacramento River, was made contingent upon rights of way being furnished free of cost or charge against that appropriation.

People interested in furthering the project undertook to procure the required rights of way by collecting subscriptions to a fund for that purpose. The city of Sacramento contributed $75,000 to the fund. All efforts proved unequal to securing enough funds for the purchase of all the lands required so the advisory board allotted moneys from the "river fund" for the purpose, and $71,996 have been expended. In a few cases terms of purchase could not be arranged with the owners and condemnation suits were brought. The last of these is now pending in the United States court at San Francisco.

San Joaquin River Survey.—In 1912 congress appropriated $32,277.50 for the purpose of making a detailed survey of San Joaquin River above Stockton, with a view of determining the feasibility of improving navigable conditions on that stream throughout its course in the valley. The appropriation was made available only on condition that California should provide a like sum. The legislature of 1913 made an appropriation of the same amount, but owing to the aggregate of appropriations made far exceeding the visible revenues the bill failed to receive executive approval, but to meet the requirements of the congressional act $32,277.50 was allotted from the state's "river fund," and placed at the disposal of the federal engineers for the purpose stated. The survey has been in progress during the latter part of 1913 and the summer of 1914.

Survey of Mountain Reservoirs.—In the light of irrigation enterprises in the Sacramento Valley already inaugurated and the vast extent of territory requiring irrigation for its full development, it is realized that soon the draft of water from the rivers for that purpose will greatly reduce the summer flow now available and needed for navigation.

It is needful to know to what extent the summer flow withdrawn for irrigation can be replaced by flood waters stored in the mountains. The Department of Engineering entered into a cooperative arrangement with the United States Reclamation Service for the survey of certain reservoir sites in the Pitt River basin to ascertain their actual worth for storage and to serve as a basis for releasing from the existing reserve all lands not actually required for the dams and reservoirs.

The sum of $2,500 was allotted from the river fund to meet a like sum provided by the Reclamation Service. The field surveys have just been completed and Mr. O. W. Peterson, the engineer in charge, has been transferred to San Francisco to arrange the data collected.

Flood Flow Measurements.—Heretofore it has always been impracticable to measure the flood flows in the streams after entering the valley for the reason that they were continually spilling their water over the banks and receiving accessions from tributaries. Arrangements have

been made to make such measurements at any time that the streams may reach flood stage this winter, not only in the rivers themselves, but also in the overflow basins, should water reach them.

The data so obtained will be of great assistance in the study of flood planes and design of flood channels for the great flood control project.

The sum of $2,000 has been allotted for these measurements from the river fund.

FLOOD CONTROL ON OTHER STREAMS.

Eel River.—The legislature of 1909 made an appropriation of $25,000 to continue the work of bank protection on Eel River in Humboldt County. The efforts of the department since that have been directed in repairing and protecting work that had been placed under an appropriation made in 1907. By terms of the act (chapter 502, 1909) no new work could be undertaken by the Department of Engineering until a deposit of one half of the estimated cost shall be made by the owners of property to be benefited. No application to have new work executed was made until late in the summer of 1912. The State Engineer personally examined the situation and concluded that it would be impossible to complete any works undertaken so late in the season, and any structures uncompleted would, when the floods came, be in danger of utter destruction.

The situation on Eel River is a very difficult one, and it is believed that radical changes must be made in the methods of control in order to obtain permanent and effective results. To enable the department to formulate plans for effective protection works it is necessary to have complete surveys of the ground, which surveys have since been made and training works built to direct and control the flood waters of this turbulent stream.

Mad River.—The legislature in 1913 appropriated $15,000 for protection work along the banks of Mad River in Humboldt County. This stream has given a great deal of trouble from eroding its banks, in some instances having washed away 80 acres in a body of rich garden soil. The appropriation act provided that the owners of land to be protected should contribute an amount equal to that expended by the state.

The beneficiaries deposited $5,108.50 in the state treasury to the credit of the fund and work provided under the law has been executed and paid for to the extent of $7,187.70. Other work has been completed and adjustment of accounts are being made. The work has been under the direction of Mr. Rasmus Anderson, member of the county board of supervisors, who has been indefatigable in efforts to accomplish the work in time to afford protection against the floods of the coming winter.

Financial Statement.—The expenditures of moneys appropriated for river work are exhibited in the following table:

TABLE 7.

Account of appropriations and expenditures by the state and the government in cooperation with the state for rectification of rivers and flood control.

Locality	Purpose	Amount allotted or expended	Amount charged to	
			State appropriations	Cooperating agency
Sacramento River—	1912-1913.			
Chico-Colusa	Snagging, etc.	$12,577 68	$12,577 68	
Crouch Landing	Bank protection	15,000 00	7,500 00	$7,500 00
Grimes	Bank protection	1,985 33	1,085 33	900 00
Tisdale Weir	Repairs and clearing	527 37	527 37	
Collins Eddy	Bank protection	8,000 00	3,000 00	5,000 00
Knights Landing	Repairs	31 75	31 75	
Elkhorn Weir	Clearing	1,392 04	1,392 04	
City of Sacramento	Levee protection	5,000 00	5,000 00	
Oak Hall District, No. 535	Bank protection	76,593 90	37,593 90	39,000 00
Freeport	Bank protection	881 61	881 61	
Brannan Island	Bank protection	4,352 96	2,082 92	2,270 04
Sherman Island	Bank protection	1,193 09	596 55	596 54
Feather River—				
Marysville, Vernon	Snagging, etc.	16,899 01	15,399 01	1,500 00
Nelson's Bend	Cut off	21,249 37	10,749 37	10,500 00
San Joaquin River—				
Smith's canal	Bank protection	1,117 00	558 50	558 50
District No. 17	Bank protection	25,065 42	12,532 71	12,532 71
District No. 544	Repairs	239 84	239 84	
Paradise Bend	Bank protection	20,911 50	10,355 75	10,555 75
New Banta Rec. District	Bank protection	12,000 00	6,000 00	6,000 00
Calaveras River	Levee, control and repairs	5,144 16	2,232 08	2,912 08
Miscellaneous.				
Widening Sacramento River	Rights of way	$71,996 10	$71,996 10	
Pit River survey	Reservoir sites	5,000 00	2,500 00	$2,500 00
Sacramento valley	Flood measurement	2,000 00	2,000 00	
San Joaquin valley	Delta channels	1,703 11	1,703 11	
San Joaquin valley	By United States	64,555 00	32,277 50	32,277 50
Brush mattresses	Maintenance	843 94	843 94	
Equipment and general	Expenses	10,847 37	10,847 37	
Totals		$387,107 55	$252,504 43	$134,603 12
Special appropriations.				
Eel River	Flood protection	$25,000 00	$25,000 00	
Mad River	Flood protection	15,000 00	7,500 00	$7,500 00
Reclamation board	Flood investigations	10,000 00	10,000 00	
Reclamation board	Flood investigations 1913-14	20,000 00	20,000 00	
Totals		$70,000 00	$62,500 00	$7,500 00
Recapitulation.				
Sacramento River		$127,535 73	$72,269 15	$55,266 58
Feather River		38,148 38	26,148 38	12,000 00
San Joaquin River		59,333 76	29,686 80	29,646 96
Calaveras River		5,144 16	2,232 08	2,912 08
Miscellaneous		156,945 52	122,168 02	34,777 50
Special—flood control, etc.		70,000 00	62,500 00	7,500 00
Totals		$457,107 55	$315,004 43	$142,103 12

Plate XXII—A. An Old Mining Dam. (Courtesy of W. P. Ireland.)

B. An Old Dam Faced With Lumber—Collapsed, 1914. (Courtesy of W. P. Ireland.)

C. A Power Ditch and Flume. (Courtesy of W. P. Ireland.)

MISCELLANEOUS.

The Department of Engineering, as explained in an earlier paragraph, has duties not included in the foregoing; some prescribed by statute and others arising from the comities of professional relations with the public.

State Supervision of Dams.—Whether persons or corporations should be permitted to construct high dams in the streams of the state impounding immense bodies of water, which, should the dam fail, would carry destruction to communities below without being subjected to state supervision, is a question that is receiving much attention.

In some states laws have been enacted requiring the plans of all such structures to be approved by state authorities and the construction executed under the supervision of a responsible state official.

One dam is being constructed in California which it is said will impound nearly one half million acre-feet of water—21,789,000,000 cubic feet. Think of the havoc such a body of water would cause should it be suddenly released by a collapse of the dam. Another is being constructed on another stream that it is reported will be three hundred feet high.

It is presumed the companies which are constructing these stupendous works have taken all precautions that human foresight can invoke to prevent an accident that would destroy their valuable property, but they may be deceived by employees.

In discussing this question in a former report of this department the following was stated:

> An instance came under the notice of the department within the last few months. A dam had been constructed in a narrow canyon and a reservoir created. From the time of its construction disquieting rumors obtained circulation in the communities situated along the course of the stream in the valley below that the dam was unstable. The owners scouted the idea that it was unsafe, exhibited the plans and specifications, which had been prepared by a man of known engineering ability, and pointed to the fact that the company would be a great sufferer in case of failure, and asked if that were not enough guarantee that all care had been taken to make the structure safe.
>
> The State Engineer was appealed to by those who felt that their lives and property were jeopardized, and finally the company consented to permit the dam to be examined, and agreed that if it was found defective such measures as were necessary would be applied.
>
> An inspection revealed the fact that in construction the specifications had been grossly ignored, and that structural members were strained to breaking limit, and in one instance had actually broken. Remedial measures were prescribed and applied as agreed upon.

Here the owners of the property were resting secure in the belief that good plans and specifications had been followed in constructing a safe structure, but in fact the specifications had been ignored, and the people in the canyon below were in danger of destruction in the event

of a probable accident, and no authority had existed to see that the plans and specifications were complied with.

In the case cited the terms of the specifications had been deliberately violated, because, if not detected, a greater profit would be made, and if the fraud should be discovered there was no penalty prescribed for it.

Another incident recently occurred wherein the people of communities below an immense reservoir to be constructed, and upon which work had commenced, were fearful that the proposed dam would not be safe. The State Engineer visited the work and after a friendly conference with the representatives of the company the type of dam was changed to one more suitable for the conditions at that site.

Several dams in the mountains are known to be unsafe, but the state is powerless to compel their owners to make them safe. It is true, those in mind are small and being situated so far back from centers of population, the flood wave caused by their failure would be largely dissipated before it would reach a point to do great danger. But some others are building or contemplated that when completed, will be a menace of great danger unless designed and constructed with all the safeguards possible.

It is a crime for an inspector or any workman on state work to have knowledge of fraudulent work being done and not make it known. All dams or other works, the failure of which would be dangerous to human life, should be subject to state supervision both as to design and construction, and to knowingly permit omission or commission that would weaken such a structure should be a felony entailing severe penalties.

It is believed the State Department of Engineering is the proper agency of the state to approve plans and supervise the construction of all works of the character mentioned which might become a menace to life and property in such large measure as may some of the great dams and reservoirs contemplated for hydroelectric and irrigation development in this state.

Bridges on Navigable Streams.—Under the provisions of the law (Chapter 68, Statutes 1881) the plans for any bridge which it is proposed to erect over a navigable stream in this state must be approved by the State Engineer, who is required to specify the width of opening required for the draw.

During the last year plans for two drawbridges for county highways crossing navigable streams have been approved and the width of opening therein specified by the State Engineer.

Irrigation District Bonds.—That the bonds of irrigation districts are not easily sold in the financial marts has long been realized by the managers of districts having bonds to sell, and desiring to raise money for construction, improvements or extensions of their irrigation works.

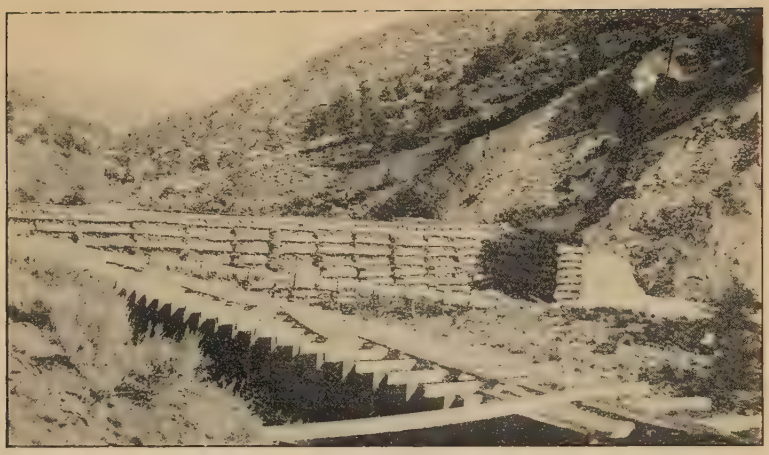
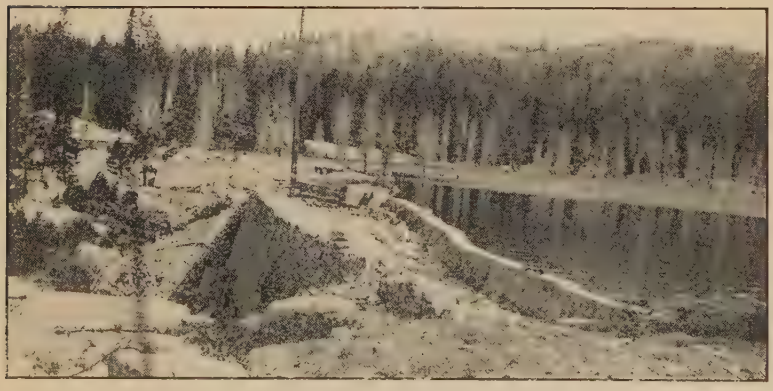


Plate XXIII—A. Power Dam, Log Cribs Filled With Rock.

B. Earth Fill Dam, Paved Slopes.



C. Rock Fill Dam, Rubble Faced.

Various reasons have been given to account for the apathy of investors toward these bonds, and one reason which was strongly urged was that irrigation district bonds were not available under the law for purchase with state funds, nor for the investment of trust funds held by banks.

An attempt to cure this defect was made by the enactment of a statute (Chapter 157, 1911, supplemented by Chapter 3, Ex. Sess. 1911), authorizing investments to be made as above, provided the project of the district should be approved by a commission composed of the Attorney General, State Engineer, and State Superintendent of Banks.

This provision for validation did not seem to stimulate the sale of such bonds, and it was explained that the statute was not supported by the constitution. Therefore an amendment to the constitution was submitted at the general election held in November, 1912, and the legislature amended the bond validation act, and the act providing for the organization of districts in many important particulars.

The most important features of the laws enacted are epitomized as follows:

To organize a new district the project must first be submitted to the State Engineer who investigates and reports as to whether or not a sufficient supply of water is available or may be acquired by any practicable means, including condemnation of existing rights, and the feasibility of the project.

Whenever it is deemed necessary to issue bonds for the purpose of constructing works or improving, extending or enlarging the system, the plans therefor shall be submitted to the State Engineer, who must examine such plans and make such examinations of the project as he deems necessary. He reports his conclusions as to water supply and feasibility of the plans.

Bonds issued for the stated purposes are twenty to forty year bonds and bear such interest as determined by the board of directors, but not to exceed 6 per cent per annum, payable semi-annually. Bonds must be sold on competitive bids to the highest and best bidder.

These two features are very important changes in the law. Formerly the interest was fixed at 5 per cent and no bonds could be sold below par.

Bonds that were authorized but not sold before the foregoing provisions became effective may be given the same privileges upon a two-thirds vote of the district.

During construction of any work to be paid for out of the proceeds of the sale of bonds, progress reports are required to be made to the State Engineer.

Annual statements of the financial transactions of the district are required to be made also to him.

The State Engineer may at any time make examination of the affairs of any irrigation district or call upon the officers thereof for such information as he may desire and make such report thereon as he may deem advisable.

The bond validation act above referred to, amended by chapter 366, Statutes of 1913, provides that when the directors of a district deem it advisable to have the district's bonds made available for investments for all trust funds, and for funds of all insurance companies, banks, both commercial and savings, trust companies, and for state school funds, and other public funds which may legally be invested in bonds of cities, counties, school districts or municipalities, and for deposit as security for the performance of any act, the said board of directors may by resolution so declare, and file a copy of the resolution with the bond commission.

The bond commission, composed of the three state officers above named, make investigations of the affairs of the district, particularly upon the following points:

(*a*) The supply of water available for the project and the right of the district to so much water as may be needed.

(*b*) The nature of the soil as to its fertility and susceptibility to irrigation, the probable amount of water needed for its irrigation and the probable need of drainage.

(*c*) The feasibility of the district's irrigation system and of the specific project for which the bonds under consideration are desired or have been used, whether such system and project be constructed, projected or partially completed.

(*d*) The reasonable market value of the water, water rights, canals, reservoirs, reservoir sites and irrigation works owned by such district or to be acquired or constructed by it with the proceeds of any of such bonds.

(*e*) The reasonable market value of the lands included within the boundaries of the district.

(*f*) Whether or not the aggregate amount of the bonds under consideration and any other outstanding bonds of said district, including bonds authorized but not sold, exceeds 60 per centum of the aggregate market value of the lands within said district and of the water, water rights, canals, reservoirs, reservoir sites and irrigation works owned, or to be acquired or constructed with the proceeds of any of said bonds, by said district, as determined in accordance with paragraphs (*d*) and (*e*) of this section.

(*g*) The numbers, date or dates of issue and denominations of the bonds, if any, which the commission shall find are available for the pur-

Plate XXIV. Goodwin Dam, Stanislaus River, Headworks South San Joaquin and Oakdale Irrigation Districts.

Plate XXV. La Grange Dam, Tuolumne River. (From Report of Turlock Irrigation District.)

poses provided for in section 7 of this act, and, if the investigation has covered contemplated bonds, the total amount of bonds which the district can issue without exceeding the limitation expressed in paragraph (*f*) of this section.

The written report and findings of the commission is filed in the office of the State Controller, and if the commission finds that the project is feasible and that the outstanding and proposed bonds do not amount to more than 60 per cent of the reasonable value of the property within the district including the irrigation works, water and water rights and other property of the district, thereupon all of said bonds become eligible to certification for the purposes enumerated above.

Upon any eligible bond being presented to the Controller he attaches thereto a certificate in the following form:

SACRAMENTO, CAL., (insert date).

I, _____, Controller of the State of California, hereby certify that the within bond, No._____ of issue No._____ of the_____irrigation district, issued_____ (insert date), is in accordance with an act of the legislature of California approved _____a legal investment for all trust funds and for the funds of all insurance companies, banks, both commercial and savings, trust companies, the state school funds and any funds which may be invested in county, municipal or school district bonds, and it may be deposited as security for the performance of any act whenever the bonds of any county, city, city and county, or school district may be so deposited, it being entitled to such privileges by virtue of an examination by the state engineer, the attorney general and the superintendent of banks of the State of California in pursuance of said act. The within bond may also, according to the constitution of the State of California, be used as security for the deposit of public money in banks in said state.

_____

Controller of State of California.

The effect of the certification of bonds as outlined in the foregoing is to make irrigation district bonds available for all purposes for which county and municipal bonds are available, a privilege that had been denied to them.

The State Engineer has made the preliminary examinations under the first act above discussed (chapter 578, 1913) for the organization of new districts or proposed issue of bonds for organized districts as follows: Anderson-Cottonwood District in Shasta County; Oakdale, Modesto, Turlock and Dry Creek districts in Stanislaus County; Alpaugh, Tulare County; Black Rock, Inyo County; Little Rock Creek, Los Angeles County; La Mesa, Lemon Grove and Spring Valley District, San Diego County and Imperial District, in Imperial County.

The conditions attending the last named district are peculiar. Nearly half a million acres of absolutely barren desert have been transformed into an agricultural paradise by the application of water brought from the Colorado River.

The enterprise was developed by a private corporation which built a canal diverting from the river in California, but within less than a mile from the head the canal crosses into Mexico and runs nearly fifty miles in foreign territory before returning across the international boundary line, where it begins to deliver water to lands in California.

Serious breaks in the river bank caused the river to forsake its channel leading to the Gulf of California and to adopt the canal as its course to the bottom of Imperial Valley, more than 300 feet below sea level. The cost of closing the breaks and restoring the river to its original course, with judgments for damages caused by the runaway waters, involved the company in financial difficulties which threw its affairs into the hands of a receiver.

The Imperial Irrigation District was formed for the purpose of taking over the property of the irrigation company. The State Engineer made an exhaustive investigation of the whole enterprise and reported that the property was worth the amount of the obligations, about $3,000,000, but that if purchased the district should provide a fund of $500,000 and maintain it as an emergency fund to meet exigencies likely to arise at any time from the vagaries of Colorado River.

A constitutional difficulty also existed in that municipalities were prohibited from owning property outside of the state.

The district has held an election, and by a large majority voted in favor of issuing bonds to the extent of $3,500,000 for the above stated purpose.

A constitutional amendment authorizing municipal corporations to own property outside of the state was proposed by the last legislature and its adoption at the general election in November seems highly probable.

The bond commission has investigated and found favorably upon the bond issues of five districts—one under the provisions of the original "validation" act, chapter 157, 1911, and four under the amended act, chapter 366, 1913, as follows:

TABLE 8.

Irrigation districts investigated and bond issues approved by the Irrigation District Bond Commission.

Name of district	Area of district, acres	Amount of bonds approved	Value of all property	Per cent of bonds to property values
San Ysidro, act of 1911	485	$25,000	$61,400	44
Oakdale, act of 1913	74,146	2,000,000	7,392,406	27
South San Joaquin, act of 1913	71,050	3,835,000	11,748,416	33
Modesto, act of 1913	81,143	2,267,000	16,516,000	14
Turlock, act of 1913	175,566	2,662,000	28,458,180	9
Totals	402,390	$10,789,000		

SOUTH SAN JOAQUIN IRRIGATION DISTRICT
Caswell
Lathrop
Manteca
Avena
Atlanta
Escalon
Cometa
Thalheim
Morena
Ripon
Huntley
Riverbank
Stewart
Solida
Glauston
Empire
MODESTO
Modesto and Empire Traction Co.
Tuolumne City
Ceres
Keyes
Stanislaus River
Tuolumne River
Lateral No. 1
Lateral No. 2
Lateral No. 2½
Lateral No. 3
Lateral No. 4
Lateral No. 4a
Lateral No. 5
Lateral No. 5½
Lateral No. 6
Lateral No. 7
Drain Ditch
T. 1 S.
T. 2 S.
T. 3 S.
T. 4 S.
T. 5 S.
T. 6 S.
R. 7 E.
R. 8 E.
R. 9 E.
R. 10

The investigations for the bond commission are made by an employee of the Department of Banking detailed for the purpose, cooperating with engineers detailed from the regular staff of the Department of Engineering, or employed specially. The law requires the districts to pay the expenses of making the investigations for the bond commission.

In the matter of the preliminary investigations made by the State Engineer for the organization of districts or the issuance of bonds—the law directs the State Engineer to make the investigations but is silent with regard to the expenses of making such investigations. The practice has heretofore been to detail an engineer from the office holding a statutory appointment, and depend upon the organization committee to provide funds to defray traveling expenses. This has been necessary for the reason that the contingent fund of the department has never been large enough to meet the ordinary claims against it.

It has not been altogether satisfactory to resort to the expedient stated. In one instance the agent was called to the most distant part of the state, paid his fare for traveling several hundred miles, several days' hotel bills and other accommodations, all from his private funds, and was not reimbursed until more than a year had elapsed. It is submitted that when an employee of the state must travel and incur expenses in the performance of mandatory duties, there should be provision for reimbursing him.

Reverting to those provisions of the law heretofore quoted which provides that plans of work for which bonds are to be issued must be submitted to the State Engineer, and that on work being executed to be paid for from the sale of bonds, progress reports must be rendered to him, it is desired here to call attention to the fact that while the law says he may make a report as to such work, it gives him no power to stop the work if it is unsatisfactory or to compel a compliance with the plans and specifications that he had approved.

It is urged that, having given its approval to the enterprise, and in a measure loaned its credit in the validation of the district's bonds, the state should properly have the right conferred by the act to pass upon the sufficiency of the plans, but in addition its agent should be clothed with all the authority necessary to compel the construction of the works strictly according to those plans, and to his complete satisfaction. This matter is commended for consideration.

IRON CANYON PROJECT.

For many years a project has been agitated to construct a dam in Sacramento River at Iron Canyon, a short distance above Red Bluff, for the purpose of creating a large reservoir which would serve for irrigating many thousands of acres of land in Sacramento Valley, as well as serve to diminish the dangerous flood flows of the river.

The matter has been under consideration by the United States Reclamation Service for a number of years, and a preliminary investigation was made of several storage reservoirs in 1904–5. Later investigations were resumed by the service, and as far as conducted at that time, the results were embodied in a report published in a report of the United States Senate Committee on Irrigation and Reclamation of Arid Lands, sixty-first congress, third session.

An organization of land owners, county authorities, civic bodies and others interested in the subject was formed under the name of the Iron Canyon Project Association to further the matter.

This association provided funds in 1913 to enable the reclamation service to further prosecute its investigations, which were completed and presented to the Secretary of the Interior a few months ago.

The investigations were made by officers and employees of the United States Reclamation Service, and the report thereon compiled by E. G. Hopson, supervising engineer, in conference with John T. Whistler, engineer, and G. Stubblefield and O. W. Peterson, assistant engineers.

Several variations of the project were considered and tentative plans, with estimates worked out. These several variations cover projects for irrigation alone; irrigation with power development; irrigation and flood control; irrigation with power development and flood control; and either phase coupled with or omitting consideration of navigation in the river below. Altogether some ten combinations were estimated upon.

The Secretary of the Interior appointed a board of review to consider the investigations of the project and to report thereon. The board was composed of the following: Brigadier General W. L. Marshall, ex-Chief of Engineers, United States Army, chairman; Mr. D. C. Henny, Acting Chief Engineer, United States Reclamation Service; W. F. McClure, State Engineer, State of California, and Mr. H. T. Cory, consulting engineer, of San Francisco, representing individual and corporate interests which would be affected by the project.

The board of review met and went over the field covered by the project and reported its conclusions to the Secretary of the Interior, to be published as a document from the United States Reclamation Service.

ECONOMIC RESEARCH.

From the beginning of its existence the government of the United States has been engaged in making surveys of its territory. For many years the principal surveys on the land were conducted by army engineer officers under the direction of the War Department. Later the Department of the Interior took charge of the survey of public lands, and in 1879–80 the United States Geological Survey was organ-

ized under that department with Clarence King as director. The first comprehensive report was that for the years 1880–81, published in 1882 by J. W. Powell, director, and was devoted almost wholly to the treatment of structural geology. (The first annual report by King, in 1880, only dealt with the plans of the organization.)

The report of 1883 took up the subject of paleontology and mineralogy. In 1884 the new subjects treated were topography, artesian wells, and paleobotany. The report of 1885 mentions new methods in silver determinations, reports on swamps, and on flora. In 1886 salt making was introduced into the investigation. In 1886–87 the study of petroleum and gas was taken up, and the researches of the survey reached California in a "Quarternary History of Mono Valley," "Geology of Lassen Peak District," and "Geology of Quicksilver Deposits of Pacific Slope."

The report of 1887–88 discussed the great Charleston earthquake. Part II of the tenth annual report 1888–89 was devoted exclusively to irrigation. Each succeeding year has witnessed the expansion of the scope of investigation until now it includes so many economic subjects that the survey is organized into eight branches, subdivided into twenty-seven divisions, and each division is again subdivided into sections according to the subjects to be investigated by it. The result of the great diversity of subjects brought under examination and analyses is that the United States Geological Survey has become a most valuable bureau of research and information.

The survey now employs nearly 1,000 people, most of whom are experts in their respective specialties. So reliable is the information obtained considered by those interested that the bulletins and publications of the survey are eagerly sought, and to supply the demand nearly 1,500,000 copies a year are printed for distribution. Indeed, the ability of these experts is so well recognized the world over that the survey frequently suffers loss by the resignations of its investigators, whose services are sought by other governments and by industrial concerns operating in this and in foreign lands. Men have been called to conduct investigations in Mexico, Canada, Honduras, Peru, China, Africa, and other countries.

Other branches of the federal government, such as the Office of Experiment Stations, Office of Public Roads, Forestry Service, etc., are engaged, coordinately with the Geological Survey, in conducting investigations along the lines of research pertinent to their respective fields of public service. The government, through these coordinate branches, is so well prepared with their several organizations, experienced staffs and complete equipment for accurate investigations along extensive lines of economic development, that their reports are sought for by

private and public interests, and the accuracy of their statements is accepted without question.

The activities of the United States Geological Survey in California during the last two years has been both extensive and varied. The geologic branch has conducted examinations and study of gold deposits in Trinity, Shasta, and Sierra counties; geology and ore deposits of the Randsburg region, geologic structure and paleontology of the White Mountains, Inyo County; silver-lead deposits of Darwin. Extensive investigations and study have been made of deposits of magnesite, of borates, potash, nitrates and other valuable salines.

Reconnaisances made of the chromite and asbestos deposits in Shasta; talc and celestite in San Bernardino County; of semi-precious gems such as tourmaline.

The troubles experienced in some of the oil fields from infiltrating water has been investigated and remedial measures studied.

The coal fields of Monterey County were examined, as well as coal and oil fields in other portions of the state.

It may not be generally known that California has within its borders coal-bearing lands on the public domain. The Geological Survey is called upon to make examinations of such lands, to furnish information for their withdrawal from entry, appraisal or restoration.

During the last year, as the result of the examinations made by the survey, 222,139 acres of lands in California have been released from withdrawal as coal-bearing, leaving only 17,764 remaining reserved from sale. Of these reserved lands 7,720 acres have been appraised at a value of $585,086, or an average value of $75.70 an acre—quite an advance over the price of $2.50 an acre that the government received for more valuable lands before the present system was established.

Other Mineral Lands Are Handled in the Same Way.—Long ago California oil producers undertook to convince the Navy Department of the superiority of oil as a fuel for warships, but not until 1912 did the government become convinced of that fact and that the public lands might contain a vast store of the fuel. In that year two naval petroleum reserves were created in California, aggregating 68,249 acres and estimated to contain 250,000,000 barrels of oil. The last report of the director of the survey shows that during the year ending June 30, 1914, 120,647 acres were withdrawn and 98,283 acres restored, leaving a total of 1,410,444 acres of oil lands withdrawn from public entry.

Potash is a mineral occurring in the barren basins of the desert regions. To prevent these valuable deposits falling into the possession of speculators who would create a monopoly of the product, areas of known potash-bearing soils in California were withdrawn in 1913 to the extent of 94,407 acres. None was added to this area in 1914, but

examinations by the survey resulted in the release of 370 acres, leaving 94,087 acres still reserved.

In 1909 congress passed a law known as the enlarged-homestead act, applying to homestead entries in twelve western arid states. This act permits the entry by one person of 320 acres of "non-mineral, non-irrigable, unreserved, and unappropriated surveyed public lands which do not contain merchantable timber." The lands subject to entry under the act must first have been designated by the Secretary of the Interior as not being "susceptible of successful irrigation at a reasonable cost from any known source of water supply."

Designations of lands as being of the class subject to entry under the enlarged-homestead act are made by the Geological Survey. Designations are not confined to the areas included in petitions of individual entrymen, but extend to contiguous lands of the same class. The first petitions made under the provisions of the act in California were filed in 1913, since which time the survey has acted upon 222 petitions, as follows:

Number of petitions received	222
Number of petitions approved	122
Number of petitions partly designated	8
Number of petitions refused	26
Number of petitions pending June 30, 1914	66
Total area of land designated as subject to entry under the act	850,506 acres

In order that important springs and other sources of stock water on the desert and semi-arid range lands should be protected from being monopolized, but remain accessible to the public, the Department of the Interior has from time to time created public water reserves.

The first reserve made in California was ninety-four acres, set aside in 1913; during last year 43,430 acres were reserved, making a total of 43,524 acres of reservation in the state on June 30, 1914.

The classification of the public lands with relation to their value in connection with water power development is also a function of the Geological Survey. Its operations under that head in California for the two years ending June 30, 1914, are summarized as follows:

Power site reserves.

Outstanding July 1, 1912		165,008 acres
Withdrawals 1912-1914	17,076 acres	
Restorations	13,315 acres	
		57,761 acres
Outstanding June 30, 1914		222,769 acres

None of the work of the Geological Survey above described was participated in by the state, and is cited only to illustrate the scope of the activities of the survey in its broad field of public service, the benefits of which extend to all the states.

CO-OPERATIVE INVESTIGATIONS.

Notwithstanding the large appropriations made by congress for the prosecution of the several lines of investigation carried on by the Geological Survey and other branches of the government, the field of operations, extending over the entire country and into foreign territory, is so large and the number of subjects investigated is so great, that progress is often too slow to meet the requirements of the rapid development of growing communities.

To expedite investigations that otherwise would have to wait for the work to reach them in its regular course, many states cooperate with the national government in prosecuting those lines of inquiry in which they are most interested.

In the matter of topographic surveys, nineteen states and one territory participated with the Survey while sixteen states and Hawaii cooperated in water resources investigations in 1913–1914.

Beginning in 1903, each session of the California legislature since has appropriated various sums for the purpose of cooperating with the several branches of the national government in the above mentioned surveys and the prosecution of investigations into various phases of economic development. Formerly the appropriations were made specifying a fixed sum for each subject to be investigated, but, in line with a recommendation made by the State Engineer in the first biennial report of this Department, the legislature since 1909 has made the appropriation as a whole, so that the funds could be apportioned by the Department of Engineering according to the requirement of each line of inquiry to be undertaken.

In pursuance of this provision of the appropriation act, agreements were entered into with the Director of the United States Geological Survey and with the Secretary of Agriculture, for cooperative research, and allotments were made of the funds appropriated to cover the state's portion of the expense of making the investigations. The agreements now in force are as follows:

With the Director of the United States Geological Survey, for:
- Topographic surveys.
- Water resources investigations.

With the Department of Agriculture, Office of Experiment Stations, for:
- Irrigation and drainage investigations.

These agreements are made to run only one year and are renewed annually.

The gathering of the information included in the above subjects is very properly a function of the Department of Engineering, but to provide the Department with the requisite equipment for field and

laboratory work and to maintain the necessary working force, would require a large appropriation. Furthermore, the work accomplished by the Department, acting alone, would be duplicate of a great deal that has been done before and that would follow in the regular progress of the work of the other governmental investigators.

By these cooperative arrangements the state obtains the service of already organized corps of experienced investigators possessing all the best apparatus and instruments, and for their service the state is required to pay only a portion of the operating expenses. As already stated, the appropriations made by the congress for the matters under discussion are too small to permit of any great amount of work being accomplished in any one state, but it is the policy of the government to give preference to those states which desire to cooperate, and the practice is to allot an amount equal to the state's appropriation.

It should be borne in mind that, in addition to the many advantages resulting from cooperative work, all money appropriated by the state is met by a like amount from the federal treasury and nearly every dollar is expended within the state.

The twenty states cooperating in topographic surveys and the seventeen joining in water investigations participate in the benefits flowing from the expenditure of $244,000 of government funds.

TOPOGRAPHIC SURVEYS.

The character of the cooperative topographic surveys made in accordance with the agreement with the Director of the United States Geological Survey is summarized as follows:

The order in which the field work is prosecuted in different parts of the state is fixed by agreement from time to time as the work progresses. The surveys are executed in a manner sufficiently elaborate to prepare maps upon scales which are agreed upon for different localities, and exhibit the hydrography, hypsography, public culture, and all public land and county boundary lines which are marked upon the ground.

The information secured by the surveys is published in atlas sheets of convenient size, called quadrangles. The sheets of paper are 20 by 16½ inches in dimensions, the territory embraced in each quadrangle covering 15 minutes, 30 minutes, or 1 degree of latitude and the same or longitude, according to the scale of the publication. Three scales are employed. The largest scale used in standard sheets is 1:62500, corresponding very nearly to one mile to one inch. Maps drawn on this scale are those of thickly settled communities or industrially important sections of the country. An intermediate scale of 1:125000, or about two miles to the inch is employed for the greater part of the country while the smallest scale, 1:250000, or about four miles to the inch, is used for territory of relatively slight industrial importance or

sparse population, such as the desert regions. A few special maps of important mining districts or other limited areas are issued on special scales suited to the requirements of the country mapped, when sheets are designated by name, usually that of some important physical feature, thus: Yuba City Quadrangle, Pyramid Peak Quadrangle, etc. That portion of the Sacramento Valley lying west of the Sacramento River has been published in sheets 28 by 40 inches and covering several quadrangles, the scale being 1:31680, or one half mile to the inch. These are found very convenient in studying irrigation and reclamation in these regions where projects embrace large areas.

The maps are sufficiently detailed to serve as base maps on which are represented the character of the soils and forests of the area surveyed, and show all principal objects, natural or artificial, such as streams, lakes, shore lines, reservoirs, canals, important wells, springs, railroads, highways, power-transmission lines, principal houses, villages, towns and cities, quarries, mills and other industrial plants, all with great clearness and fidelity to position.

The hypsography is shown by contour lines with vertical intervals of 5 to 100 feet, according to the smoothness or ruggedness of the terrene. The heights of important points are determined and enduring monuments and bench marks are established, the elevation and location of which are found by precise methods. Along both sides of the Sacramento River, from Suisun Bay to a point several miles above the city of Sacramento, there have been set solid concrete monuments, in which are imbedded aluminum tablets upon which are marked the elevations to the nearest foot. At frequent intervals all over the territory surveyed are placed other bench marks which consist of iron pipes set solidly in the ground and capped with a bronze or aluminum cap, marked in the same manner as the tablets on the concrete monuments. A record of the location, and the elevation in feet and fractions, of all bench marks is kept on file in the office of this Department. All elevations noted by the survey are determined by precise level lines run and checked with the utmost care, and are referred to mean sea level as deduced from long series of observations.

The United States Geological Survey conducted topographic surveys in thirty states and one territory during the fiscal year ending June 30, 1914, and mapped 19,150 square miles of territory. The total area of the country now mapped amounts to 39.6 per cent of the entire area of the continental United States and 21 per cent of Hawaii.

In California there were 6,133 square miles surveyed and mapped during 1912 and 1913, and during the year just closed 1,672 square miles were added, making a total of 7,805 square miles surveyed during the biennial period ending June 30, 1914. The total area now mapped amounts to 70 per cent of the entire surface of the state.

The surveys were made by the United States Geological Survey, and by the Survey in cooperation with the State of California. Those quadrangles surveyed in cooperation with the state represented by the Department of Engineering will be found in the report at the end of this article.

In addition to the surveys made in cooperation with this Department, the Survey, under cooperative agreement with the University of California began early in 1914 a survey of Santa Rosa quadrangle.

In addition to the cooperative surveys named, the Geological Survey has completed the survey and mapping of the following quadrangles: Petaluma, Capitola, Soledad, Priest Valley, Mount Morrison, Mojave.

Work was begun upon Seiad, Sawyers Bar and Crucero quadrangles, and revision commenced on San Francisco, Concord, Hayward and Alameda quadrangles, while the map of Kern River Oil Fields was completely revised.

The topographic work now in progress which is of the greatest immediate importance is the survey of the Great Valley.

Special effort was concentrated upon the survey of the Sacramento Valley, in response to the great demand for information required by the rapid development of irrigation and reclamation enterprises. The survey was completed and the maps are being rapidly published. These maps give contours at five-foot intervals up to 300 feet elevation, that being taken as the upper limit of practical irrigation from the streams entering the valley. A consolidated map of the entire valley on a small scale and showing 25-foot contours has also been published. The survey of the Sacramento Valley being completed, the field parties were transferred to the San Joaquin Valley, that territory being considered next in importance. The field work in the valley has progressed about one third the length of the valley. Maps of this region are very greatly needed in the study of flood control problems, reclamation and navigation now being vigorously prosecuted.

The cooperative topographic surveys have been conducted under the supervision of Mr. George R. Davis, geographer in charge of the Pacific Division, directed by Mr. R. B. Marshall, chief geographer.

Their report in detail for the two years ending June 30, 1914, here follows:

Report of topographic surveys in cooperation between the United States Geological Survey and the State of California, for the fiscal years beginning July 1, 1912, and ending June 30, 1914.

In accordance with the cooperative agreements signed August 24, 1912, by George H. Ashley, acting director, and July 1, 1913, by George Otis Smith, director, for the United States Geological Survey, and September 6, 1912, and July 22, 1913, by W. F. McClure, State Engineer, for the State of California, the federal survey allotted $14,000 each year, and the state an equal amount, for coperative topographic surveys in the State of California for the fiscal years ending June 30, 1913, and June 30, 1914.

The following is a summary of the field and office work accomplished during the above period under the general direction of R. B. Marshall, chief geographer, and under the immediate supervision of George R. Davis, geographer in charge of the Pacific Division:

TABLE 9.

Field work.

Quadrangle	Counties	Publication on scale of	Area in square miles mapped	Primary levels		Secondary traverse miles	Triangulation	
				Miles	Permanent marks		Stations occupied	Stations marked
Atwater	Merced						1	
Avena	Stanislaus San Joaquin.	1:31,680	59					
Bachelor Valley	Calaveras Stanislaus.	1:31,680	59					
Bradley	Monterey	1:31,680	6					
Burnham	San Joaquin	1:31,680	59					
Capitola	Monterey Santa Cruz.						2	2
Ceres	Stanislaus						2	
Cooperstown	Stanislaus Tuolumne.	1:31,680	59			777	3	1
Copperopolis	Calaveras Stanislaus. Tuolumne.	1:62,500	78			22		
Cressy	Merced						3	2
Crevison Peak	Stanislaus Merced.	1:31,680					1	1
Denair	Stanislaus	1:31,680	12				4	
Dickenson	Merced Stanislaus.	1:31,680	59				3	
Empire	Stanislaus	1:31,680	59				1	
Gilroy Hot Springs	Stanislaus						2	3
Hollister	Santa Clara San Benito.						1	
Las Garzas Creek	Stanislaus Merced.						1	1
Lathrop	San Joaquin	1:31,680	59					
Lone Tree	Contra Costa	1:31,680	30					
Manteca	San Joaquin	1:31,680	59					
Merced	Merced						1	
Midway (Resurvey)	San Joaquin	1:31,680	9					
Montpellier	Merced Stanislaus.	1:31,680	59				3	1
Morgan Hill	Santa Clara						3	5
Mt. Boardman	Alameda Santa Clara. Stanislaus.						3	3
Mt. Hamilton	Santa Clara Alameda.						1	1
New Almaden	Santa Clara Santa Cruz.						1	
Number V	Merced						4	3
Number VI	Merced						3	3
Oakdale	Stanislaus	1:31,680	59					
Orestimba Creek	Stanislaus						3	4
Patterson	Stanislaus	1:31,680	24				2	2
Pajaro	Monterey Santa Clara. Santa Cruz.						3	2
Peters	San Joaquin	1:31,680	59					
Planada	Merced						1	2
Reservoir	Stanislaus	1:31,680	59				3	
Ripon	San Joaquin Stanislaus.	1:31,680	59			12	3	
Romain	San Joaquin Stanislaus.	1:31,680	24			65		2
Salida	Stanislaus	1:31,680	59				5	
San Ardo	Monterey	1:31,680	4					
San Luis Creek	Stanislaus						1	
Tesla	Alameda San Joaquin.						1	1

TABLE 9—Continued.

Field work.

Quadrangle	Counties	Publication on scale of	Area in square miles mapped	Primary levels		Secondary traverse miles	Triangulation	
				Miles	Perm. marks		Stations occupied	Stations marked
Thalheim	San Joaquin, Stanislaus.	1:31,680	59					
Trigo	San Joaquin, Stanislaus.	1:31,680	59					
Tracy	Monterey	1:31,680	45				1	
Union Island	San Joaquin	1:31,680	32					
Vernalis	San Joaquin	1:31,680	59					
Waterford	Stanislaus	1:31,680	59				2	
Westley	Stanislaus	1:31,680	59				2	
Westport	Stanislaus	1:31,680	59				3	
San Joaquin Valley				300	82			
Middle Fork American River.	El Dorado, Placer.	1:31,680				*43		
Pit River	Lassen, Shasta.	1:31,680				*42		
San Joaquin River	Fresno	1:31,680				*124		
Totals			1,444	300	82	1,085	73	39

*River profile surveys. (Funds for this river profile work provided by State Board of Control.

The following members of the Topographical Branch were engaged in the field work:

Topographic Mapping:

Duncan Hannegan, Topographic Engineer
J. P. Harrison, Topographic Engineer
J. G. Staack, Topographer
W. N. Vance, Topographer
A. E. Burkland, Topographer
E. R. Bartlett, Assistant Topographer
Chas. Hartmann, Assistant Topographer
H. W. Peabody, Assistant Topographer
T. P. Pendleton, Assistant Topographer
O. G. Taylor, Assistant Topographer
S. E. Taylor, Assistant Topographer
J. B. Leavitt, Assistant Topographer
F. A. Danforth, Junior Topographer
L. V. Fees, Junior Topographer
R. B. Kilgore, Junior Topographer
D. H. Watson, Junior Topographer
S. H. Birdseye, Junior Topographer
C. A. Stonesifer, Junior Topographer
R. M. LaFollette, Topographic Aid
H. S. Leicht, Topographic Aid
Frederick Rider, Topographic Aid.

Triangulation:

C. F. Urquhart, Topographic Engineer
C. L. Nelson, Topographic Engineer
W. R. Chenoweth, Junior Topographer
R. B. Kilgore, Junior Topographer.

Levels:

D. S. Birkett, Junior Topographer.

OFFICE WORK.

The office drafting of the Avena, Bachelor Valley, Burnham, Cooperstown, Dickenson, Lathrop, Lone Tree Valley, Manteca, Midway, Mojave, Montpellier, Oakdale, Patterson, Peters, Reservoir, Ripon, Romain, Salida, Thalheim, Tracy, Trigo, Union Island, Vernalis, Westley, and Westport topographic maps was completed and the maps transmitted for engraving; and the office drafting of the plan and profile maps of the Pit River, the Middle and South Forks of the American River, and the Feather, San Joaquin, and Tuolumne rivers, was completed and the maps photolithographed. The drafting of the following incomplete maps was also commenced: 9 per cent of the Bradley, 20 per cent of the Metz, and 12 per cent of the San Ardo being finished.

The adjustment of the levels for the Ripon, Chowchilla, Slough, Dickenson, Gustine, Ingomar, Los Banos, Owens Creek, Ceres, Patterson, Cressy, Crows Landing, Deadman Creek, Denair, Dry Creek, Elgin, Empire, Salt Slough, Waterford, Westley, Westport, Romain, Madera, Newman, Salida, Montpellier, Reservoir, Volta, Nos. IV, V, VIII, and X, Stevinson, Turlock, Vernalis, Cooperstown, Mariposa, Slough, and three unnamed 7½-minute quadrangles was completed and copies of the results typewritten for publication.

Final computations for the geodetic positions for the San Juan, Morgan Hot Springs, Gilroy Hot Springs, San Antonio Valley, Romain, Westley, Black Gulch, Kern, Vernalis, Gerber, and Oso quadrangles were completed.

WATER RESOURCES.

Water, of all the natural resources with which this state abounds, has exerted the most potent influence in bringing California to the forefront among her sister states. It was water in a little mill race among the hills that first discovered to Marshall's view the glittering gold, and it was water that enabled the miners gathered from the four corners of the earth to recover from the hillsides and canyons the golden treasure hidden there. Water has converted the barren desert into fruitful gardens and orchards; it furnishes 500 miles of fresh water highways over which produce and merchandise valued at millions of dollars are carried annually between the communities within the state. It turns more than a thousand wheels, sending half a million horsepower of electric energy over thousands of miles of wire and operating the machines in shops, smelting ores, moving trains from city to city and through their streets and brightly lighting every city, town and hamlet.

The state was but performing a governmental duty, then, when it directed active investigation to be made of the wonderful potentialities of this abundant element—abundant we may think, yet with finite limits which will be reached in a period of time which is as but a moment in the life of a state.

SURFACE WATER INVESTIGATIONS.

In relation to the flow of streams, there had been some research conducted by the national government, a little by the state and more by private interests (whose records are not available for public use), but none was made systematically or on a comprehensive scale. The state,

by the State Engineering Department during its existence from 1879 to 1884, gave considerable study to the subject. The United States Geological Survey began observations of stream flow in 1894, but as the appropriation for the Survey's work over the whole United States was only $12,500, very little could be accomplished. Each year the work has extended in proportion to the funds provided; new gaging stations were established and more measurements made.

In 1903 the state legislature made an appropriation to cooperate with the United States in several lines of research and assigned $15,000 "for the purpose of gaging streams, surveying reservoir sites and canal locations, for the conservation and utilization of the flood or stream waters of the state." An agreement was made between the Board of Examiners on the part of the state and the Director of the Geological Survey for the extension of the surveys and measurements provided for by the act. The legislature has appropriated various sums for this purpose at each succeeding session, and the cooperative agreements have been renewed each year, the Department of Engineering upon its organization in 1907, succeeding the Board of Examiners as the representative of the state.

At the time the first agreement became effective, July 1, 1903, the survey had only thirty gaging stations established throughout the entire state, and several of these were temporary, being maintained only one or two years. By 1909 the number of stations had been increased to seventy.

The extension of irrigation appearing then to be the first requisite and the prime use for the waters, the earlier efforts were directed to obtaining data for that object. Therefore, most of the gaging stations were placed at sites of prospective reservoirs or near where the streams debouched into the valleys. The result of observations made at stations so placed has been to acquire data concerning possibilities of storage as well as extensive and reliable records of the quantity and variability of the flow of all of the principal streams of the state at the mouths of their canyons.

For convenience in arranging the records of the streams in groups of correlated or adjacent units for study, the state is here divided into four drainage areas, as follows:

1. South Pacific Coast.
2. North Pacific Coast.
3. The Great Valley.
4. The Great Basin.

The first area embraces all streams flowing into the Pacific Ocean south of San Francisco Bay, including the Colorado River; the second covers those lying north of the bay.

The Great Valley includes the Sacramento River and the San Joaquin Valley drainage systems; while the Great Basin area extends to all streams flowing east of the mountain range into the "Great Basin," as that great plateau is called which extends from the Sierra Nevada to the Rocky Mountains, and from southern Idaho southward over the whole of Nevada and a large part of Utah. None of the California streams in the Great Basin reaches the sea, but they either lose themselves in "sinks" or discharge into such lakes as Pyramid and Walker lakes, Nevada, Owens Lake and Honey Lake in California. Most of the streams having their origin in the Sierra of California soon cross the state line into Nevada.

The principal drainage basins embraced within each of the above named divisions wherein gaging stations have been maintained during the last two years are as follows:

SOUTH PACIFIC COAST AREA.

Sweetwater River;
San Diego River;
San Dieguito River;
San Luis Rey River;
Santa Ana River;
San Gabriel River;
Santa Clara River;
Santa Ynez River;
Santa Maria River.

The conservation and utilization of water for its various economic purposes has reached a state of development in this area probably not equaled elsewhere in the world. The extensive records obtained from the stations and measurements of the Survey have been of great value in working out the problems of economic development.

NORTH PACIFIC COAST AREA.

Eel River;
Mad River;
Klamath River (includes Trinity and Scott rivers);
Smith River.

Observations in these basins were not begun regularly until 1910 and have not extended over sufficient time to afford data for comparisons.

BIG BASIN AREA.*

Susan River;
Willow Creek;
Truckee River;
Owens River;
Walker River;
Carson River;
Mono Lake.

Nearly all of the waters of this area have been appropriated and further measurements would be of little interest excepting locally, so no reports of this region have been published since 1909. However, further data being required for studies of storage, and power, some stations have recently been reestablished.

GREAT VALLEY AREA.

Sacramento Valley;
San Joaquin Valley;
San Joaquin River Basin;
Tulare Lake Basin;
Kern River Basin.

STREAM GAGING.

Upon all of the streams named above and upon many of their tributaries, gaging stations are established for the measurements of the water flowing at those points. On the main trunk streams and on their principal branches the stations are usually permanent in character, and observers are employed to make daily observations of gage heights. The cross section of the stream is carefully measured, and a graduated rod or staff set marked in feet and subdivisions, and with the zero generally at the surface of low water, or if it can be ascertained at the height of the lowest low water known.

Measurements of the velocity of the stream are taken at intervals, effort being made to obtain each measurement at different stages of the river, so as to obtain data for calculating the rate of flow in the stream at all stages. This is called "rating the station," and a table of the flow for each foot in height shown on the gage is prepared from these measurements and calculations and it is called a "rating table."

Several methods are used to measure the quantity of water flowing in the streams but wherever practicable the weir methods, as where the water pours over a dam is used to obtain the quantity, or the velocity method, using a current meter.

*Goose Lake drainage basin topographically belongs to this area, but as the waters appear to pass under ground and feed Pit River, the drainage is included in the Sacramento Basin.

The current meter method is the one generally used, and by permission of the Director of the United States Geological Survey illustrations of the instruments used and their method of employment are herewith presented.

The several methods employed are fully described in the publications of the Survey, particularly in "Weir experiments, coefficients and formulas," designated as Water Supply Paper 200; "Turbine water wheel tests and power tables," as Water Supply Paper 180; and "Surface Water Supply of the United States 1907–8, Part IX," Water Supply Paper 251. These volumes may be purchased at a nominal price from the Superintendent of Documents, Washington, D. C.

The results of stream measurements are expressed in second-feet or acre-feet. A second-foot is the prism of water one foot deep, one foot wide and moving a foot of distance in a second of time. A stream flowing a second-foot, or as it is sometimes written a cubic foot per second, would fill a box a foot square and a foot deep every second, and amounts to 448.8 gallons a minute. In ordinary practice it is regarded as 450 gallons a minute.

An acre-foot of water is the quantity that would cover an acre of space one foot in depth.

One second-foot of water running continuously for twenty-four hours will cover an acre to a depth of 1.98 feet or amount to 1.98 acre-feet. For many computations it is sufficiently accurate to assume a second-foot to be equivalent to 2 acre-feet a day.

In California and some other states another unit of measurement is used called the miner's inch. This is, theoretically, the quantity of water that will flow through an orifice one inch square, placed at a certain distance below the surface. The depth below the surface, called the "head," varies in different states and in different localities in the same state.

The statutes of California require an appropriator to record a notice of his appropriation stating the quantity he claims "in inches under a four-inch pressure." Hydraulicians are agreed that pressure means "head" which is the vertical distance from the surface of still water to the center of gravity of the orifice. Under such conditions a miner's inch would be equivalent to 0.02 (1/50) second-foot, or, in round numbers, 9 gallons a minute.

By a statute enacted in 1903, however, it is declared that a miner's inch shall be equivalent to 1/40 second-foot, or 11.25 gallons a minute. This contradictory statute should be repealed, and one enacted requiring all quantities to be described with definite figures; gallons for domestic use or pumping, second-feet for rate of flow and acre-feet for quantity.

The results of the observations at the gaging stations established at various points on the streams of the state are published from time to time in the bulletins issued by the Geological Survey under the title of Water Supply Papers.

These published records give the following information:

Description of station, and of its characteristics.
List of discharge measurements made on the stream above.
Table of daily gage heights at the station.
Table of daily discharges.
Table of monthly and yearly discharges and run-off.

The records obtained are of inestimable value in the study of the many problems concerning irrigation, reclamation, flood control and navigation, and have been accepted and used very extensively by engineers engaged in operations under either and all of the subjects named.

The records obtained of the flow of Sacramento River and its tributaries were also used by the United States Debris Commission and the Board of Engineers for Rivers and Harbors as a basis for the plan reported to congress for the "Control of Floods in the Systems of the Sacramento Valley and the Adjacent San Joaquin Valley," a project involving the expenditure of millions of dollars. A similar project for the same purpose was proposed several years ago, before the cooperative observations above mentioned had procured complete data. The project was based upon the best information obtainable at that time of the flood flow of the streams, but in the light of later research and from the continuous records obtained it is known that works for flood control must care for about 130 per cent more water than was formerly believed to be necessary.

A reliable record, then, of the quantity of water poured into the valley by all its streams at flood is necessary to an intelligent study of problems relating to flood control. A knowledge of the amount of low water flow is requisite in discussing means of aiding navigation.

Correct information as to the daily, monthly and annual flow of each stream and of all combined is necessary in exploiting irrigation enterprises for the ten million acres of irrigable land in the Great Valley, and other millions of acres elsewhere in the state.

In furtherance of this last named object knowledge is required, too, of the extent to which surplus water can be conserved, and the flow regulated by storage reservoirs.

THE GREAT VALLEY OF CALIFORNIA.

Upon examining a map of California it will be seen that the state is traversed in a general northwest-southeast direction by two approximately parallel ranges of mountains. Near the shore line is the Coast Range, and along the eastern border is the Sierra Nevada. These two

ranges converge at the south, uniting at Tejon into one range, which continues thence southward, terminating in Cape St. Lucas, at the extremity of Lower California, Mexico. They also approach each other near Redding, until their foothill spurs meet, thus encircling the "Great Valley of California."

The Sierra is continuous and the Coast Range unbroken excepting where pierced by the outlet of the valley through Carquinez Straits. The watershed enclosed between the summits of the mountain ranges is estimated at 58,000 to 64,000 square miles in area, embracing about 40 per cent of the whole state. The valley proper is 400 miles in length from Redding to Tejon Pass, an average of 40 miles in width and contains more than 10,000,000 acres. The floor of the valley presents almost an unbroken plain, sloping gently from the hills toward the central axis and descending from an elevation of less than 500 feet at each end to tide water at the middle.

The drainage from the entire territory is effected by the Sacramento from the north and the San Joaquin River coming from the south, meeting at the head of Suisun Bay, whence their mingled waters are carried through Carquinez Straits and the Golden Gate to the Pacific Ocean.

The north portion of the Great Valley, which is traversed by the Sacramento River, is generally designated as Sacramento Valley, while the remainder is called San Joaquin Valley, although there is no physical line of demarkation separating them.

SACRAMENTO RIVER DRAINAGE.

The head of the Sacramento River is a small lake not exceeding ten acres in area, and which the geographers have not dignified with a name. It is ensconced among the pines on the south slope of Mount Eddy, one of the peaks of the Trinity Mountains, eighteen miles southwest of Mount Shasta, and at an elevation of 6,600 feet above the sea.

This tiny lakelet gives birth to a brook, which, quickly swelling to a mountain torrent, leaps down the rocky canyon in cataracts and falls as "The water comes down at Lodore," descending 3,000 feet in twelve miles. Here it is joined by Wagon Valley Creek about two miles south of the town of Sisson, and henceforth is known as the Sacramento River.

Like the Mississippi, the Sacramento has a tributary whose source is farther away than that of the main stream. Pit River rises in Modoc County, 180 miles above the confluence with the Sacramento, while the latter stream measures but fifty-six miles from Fountainhead Lake, above mentioned, to the junction. The South Fork of Pit River rises on the western slope of Warner Mountains at an elevation of 8,000 feet, while the North Fork begins about half a mile from the south end of Goose Lake. The "summit" dividing the lake from the head of Pit

River is so flat that it is scarcely distinguishable as a watershed, and as it is only a few feet higher than the normal high water surface of the lake, the latter has been known to flow over into the river. It is said that in 1881, during a severe north wind, the water was driven over the ridge for several hours. Goose Lake is twenty-eight miles long, extending about ten miles into Oregon, with several streams running into it at the north end. Although the south rim of the lake cuts it off from direct connection with Pit River, the lava formation probably permits water to pass with some freedom, and, forming springs within Pit River Basin, contributes to the flow of that stream. The Goose Lake Basin is included in the Pit River drainage by the investigators of the Geological Survey.

McCloud River is an affluent of Pit River, and a branch of it bearing the prosaic name of Mud Creek has its source on the south slope of Mount Shasta in Konwakiton Glacier, which lies between elevations of 11,000 and 13,500 feet above the sea.

SACRAMENTO VALLEY.

As before stated, the earlier measurements of stream flow were taken primarily in pursuing irrigation research, and in addition to this object, in the case of the Sacramento River, was coupled investigation of flood conditions. For these reasons the records which cover the longest series of years were taken on the streams which enter the valley at the mouths of the canyons.

The most important streams entering the valley, all of which are tributary to the Sacramento River during its course through the valley, and upon which gaging stations are maintained, with the location of such stations and the date of their establishment, are named as follows:

Sacramento River, near Red Bluff, Tehama County, 1895.
Stony Creek, near Winters, Yolo County, 1901.
Feather River, at Oroville, Butte County, 1902.
Yuba River, near Smartsville, Yuba County, 1903.
Bear River, near Van Trent Post Office, Placer County, 1904.
American River, Fair Oaks Bridge, Sacramento County, 1904.
Cache Creek, near Yolo, Yolo County, 1903.
Putah Creek, at Winters, Yolo County, 1904.

The flow of water into the Sacramento Valley as recorded at the several gaging stations above named is summarized in the following table:

TABLE 10.

Flow of water into Sacramento Valley, October 1, 1903, to September 30, 1912.

Stream	Drainage area square miles	Maximum flood flow second-feet	Maximum monthly flow second-feet	Maximum mean daily flow acre-feet	Minimum monthly flow acre-feet	Maximum annual flow acre-feet	Minimum annual flow acre-feet	Mean annual flow acre-feet	Available storage capacity acre-feet
Sacramento	10,400	278,000	254,000	4,480,000	280,000	15,900,000	6,375,000	10,846,000	[5]1,316,000
Stony Creek	601	36,000	29,300	391,000	50	894,000	----------	----------	144,000
Feather	3,640	187,000	187,000	2,450,000	42,000	9,340,000	2,069,900	6,032,000	775,600
Yuba	1,220	[6]125,000	111,000	1,060,000	17,300	4,560,000	1,126,500	3,051,800	138,000
Bear[1]	263	25,800	25,800	96,400	806	726,000	92,500	396,900	----------
American[1]	1,910	119,000	105,000	1,520,000	7,320	6,480,000	1,232,000	3,772,000	----------
Cache Creek	1,230	20,800	20,100	285,000	----------	1,280,000	250,000	697,100	176,500
Putah Creek[2]	805	37,000	30,000	453,000	29	881,000	199,000	510,800	318,000
Total	----------	----------	----------	11,000,000	378,059	----------	----------	25,887,000	2,868,100
Unmetered streams[3]	3,907	76,000	----------	----------	----------	----------	----------	----------	----------
Valley[4]	4,250	25,500	----------	----------	----------	----------	----------	----------	----------

[1]Record beginning 1903-4.
[2]Record beginning 1905-6.
[3]Estimated from 50 per cent runoff of rainfall recorded in area for storm of March, 1907.
[4]Estimated from 40 per cent runoff of rainfall recorded for storm of March, 1907.
[5]The capacity of the Big Valley reservoir on Pit River is stated to be 3,196,000 acre-feet, but as the mean annual flow of Pit River at that point for a period of five years was 713,000 acre-feet that amount is taken as the available storage capacity of the stream at that site. The capacity of Warm Springs Valley and Round Valley and others above Big Valley are omitted, as their storage would simply reduce the flow reaching Big Valley reservoir. To the Big Valley storage is added the storage of a proposed reservoir at Iron Canyon which is estimated at 603,000 acre-feet.
[6]These figures are the estimate made by the United States Debris Commission as the quantity flowing just prior to the destruction of the debris barrier below Smartsville. The maximum recorded at the gaging station was 111,000 second-feet.

TABLE 11.

Annual flow of Sacramento River and tributaries.

(Expressed in acre-feet for each year, 1903-4 to 1911-12.)

	1903-4	1904-5	1905-6	1906-7	1907-8	1908-9	1909-10	1910-11	[1]1911-12	Mean
Sacramento	15,900,000	10,600,000	11,100,000	13,700,000	7,720,000	13,400,000	8,910,000	6,375,000	6,375,000	10,846,000
Stony Creek	753,000	508,000	535,000	765,000	338,000	894,000	357,000	535,000	104,000	585,600
Feather	9,330,000	4,490,000	6,710,000	9,340,000	3,490,000	7,380,000	4,500,000	6,980,000	2,069,900	6,032,000
Yuba	4,100,000	2,400,000	3,630,000	4,500,000	1,590,000	3,880,000	2,670,000	3,510,000	1,126,500	3,051,800
Bear	[2]538,000	315,000	561,000	726,000	188,000	3,880,000	256,000	512,000	92,500	396,000
American	[2]5,046,000	2,460,000	4,762,000	5,710,000	1,450,000	4,540,000	3,540,000	6,480,000	1,232,000	3,772,000
Cache Creek	890,000	629,000	740,000	983,000	309,000	1,280,000	250,000	496,000	36,900	697,100
Putah Creek	[2]672,000	[2]475,000	583,000	691,000	199,000	881,000	228,000	483,000	56,300	510,800
Totals	37,229,000	21,877,000	28,621,000	36,475,000	15,284,000	32,780,000	20,711,000	28,906,000	11,102,100	25,887,000

[1]The "flow year" begins with the rainy season, and is registered from October 1st to September 30th, following.

[2]The figures for Bear and American rivers, 1903-04, and Putah Creek, 1903-04 and 1904-05 are interpolated, and are obtained as a proportion of the recorded flow of the nearest neighboring watershed. They are not assumed to be correct, but are inserted to show probable totals for the years when the record was incomplete.

NOTE.—Records since June 30, 1912, have not been published. The figures for 1911-12 are interpolated from unadjusted gage readings.

SAN JOAQUIN VALLEY.

This valley, as heretofore stated, is the southern portion of the Great Valley of California, and constitutes a little more than 70 per cent of it. The line separating the San Joaquin and Sacramento valleys is imaginary and lies between the Cosumnes and Sacramento rivers, extending across the head of Suisun Bay to the hills on the west side. The Cosumnes River is a tributary of the Mokelumne River and is the most northerly stream whose waters run into the San Joaquin. The valley proper, from the imaginary line mentioned to its southern extremity, measures 250 miles long and 45 miles wide, embracing an area of 7,360,000 acres.

The general slope of the valley floor is downward from south to north and from the hills at each side to the longitudinal axis. The lowest line of depression or trough is marked by a succession of lakes and sloughs in the upper portion and is occupied by San Joaquin River for the lower 160 miles.

This stream enters the valley on the east side, runs northwest across the plains to the trough, and takes a direction nearly perpendicular to its former course, continuing to Suisun Bay. The valley is thus divided by the axial trough into two unequal plains, about two thirds of the whole lying on the east side.

The larger streams flowing into the valley from the Sierra are perennial, while those from the Coast Range are torrential and intermittent in flow. The streams on both sides, after emerging from the hills, run across the intervening plains to the trough at a right angle to the direction of the valley. All being sediment-bearing streams, they have built up alluvial delta fans with the apexes at the mouths of the canyons and spreading downward over the plain.

Kings River from the east and Los Gatos Creek directly across the valley have created such fans, which unite and form a "delta dam" across the trough, shutting off the drainage of the south from running into the San Joaquin excepting when the basin so created, of which Tulare Lake is the center, fills to overflowing.

In a similar way Kern River has extended its delta across the trough and joined the McKittrick hills, separating Tulare Lake basin from the south end of the valley in which Kern and Buena Vista lakes become the depository of the drainage from the hills and mountains surrounding it on the north, east and south. All of the streams entering this end of the valley are intermittent and of little importance excepting Kern River, hence the name of that stream is given to the drainage basin.

KERN RIVER BASIN.

As stated above, this is the only stream in this region of sufficient importance to warrant a record of flow being secured. Gaging records were obtained of this stream by the State Engineering Department from 1879 to 1884. In 1893 the Kern County Land Company, which controls all of the waters of the river, established a gage at the mouth of the canyon which has been maintained ever since. The records which are furnished by the land company show that for a period of thirteen years the mean annual discharge of the stream was 683,900 acre-feet.

Other stations are maintained in the mountains by different power development companies who are engaged in or contemplate the development of power, which will be discussed later.

TULARE LAKE DRAINAGE BASIN.

The streams flowing into the basin upon which permanent gaging stations have been maintained, named in order from south to north, with the location of the stations and the year observation began, are as follows:

Tule River, 8 miles east of Porterville, 1901.
Kaweah River, below Three Rivers, 1903.
Kings River, Red Mountain, 1895.

All of the water of these streams at low and medium stages is diverted for irrigation purposes in the valley. Only flood waters ever reach Tulare Lake.

The annual flow of these streams for a period of seven years, 1904–1911, are herewith presented in table. A description of Tulare Lake and short history of its change, from being the largest body of fresh water west of the Mississippi River to a fertile body of land a thousand square miles in extent, was included in a previous article in this report discussing the question of flood control.

SAN JOAQUIN RIVER BASIN.

The San Joaquin River, as stated elsewhere, enters the valley from the east, flowing two thirds of the way across and then turning to the northwest, following in the trough of the valley to unite with the Sacramento River at the head of Suisun Bay. It is joined on its course by several large tributaries coming from the Sierra on the east.

Those which have been considered of sufficient importance to warrant the maintenance of gaging stations on them for a series of years, named in order as they appear from south to north, are as follows:

San Joaquin River station, established near Friant, 1907.
Merced, near Merced Falls, 1901.
Tuolumne, near Lagrange, 1895.
Stanislaus, near Knights Ferry, 1895.
Calaveras, near Jenny Lind, 1906.
Mokelumne, near Clements, 1904.
Cosumnes, near Michigan Bar, 1907.

There are several other streams which flow considerable quantities of water occasionally, but only reach the San Joaquin River in times of flood.

The record of total flow in the valley is not satisfactory as a basis for the study of the several problems under research, for the reason that reliable gagings are not available on some of the streams for an extended period of time. For example, the observations on the San Joaquin at Friant, and on Cosumnes River date back only to October, 1907, so that a complete record begins with the year 1908.

It will be observed that the tables of stream flow terminate the record with the seasonal year, 1911–12. There have been no reports of stream gagings published since 1912, and at the time these tables were compiled the adjusted records following the last report were not available.

Water Supply Papers 331, 359, 360, and 361, soon to be issued, will contain data of all streams measured up to June 30, 1913.

TABLE 12.

Flow of Kern River.

	Discharge in second feet			Total, acre-feet
	Maximum	Minimum	Mean	
1904–05	3,039	194	756	548,000
1905–06	9,505	175	2,538	1,840,000
1906–07	4,504	433	1,606	*869,000
1907–08	2,080	272	910	*380,000
1908–09	8,851	249	2,400	1,630,000
1909–10	4,656	248	1,020	740,000
1910–11	4,623	243	1,384	1,000,000
Mean annual flow for 7-year period			1,515	1,001,000

*Records for this period incomplete.

TABLE 13.

Flow of streams in Tulare Lake Basin.

	TULE RIVER				KAWEAH RIVER				KINGS RIVER				Total of three streams, acre-feet
	Discharge in second-feet			Total acre-feet	Discharge in second-feet			Total acre-feet	Discharge in second-feet[1]			Total acre-feet	
	Maximum	Minimum	Mean		Maximum	Minimum	Mean		Maximum	Minimum	Mean		
1904	2,305	7	101	73,551	2,920	46	564	408,272	15,700	130	2,586	1,880,846	2,702,669
1905	822	7	101	73,610	2,060	40	421	304,700	9,595	150	1,781	1,289,000	1,667,310
1906	4,530	37	464	338,000	8,160	75	1,520	1,110,000	26,600	205	5,380	3,920,000	5,368,000
1907	2,300	28	216	155,000	3,400	75	814	589,000	15,600	265	3,770	2,730,000	3,474,000
1908	1,230	6	105	75,600	1,600	42	335	243,000	6,290	265	1,400	1,020,000	1,338,000
1909	5,430	35	446	323,000	9,200	72	1,170	850,600	20,300	280	4,040	2,920,000	4,093,000
1910	1,940	5	101	79,000	4,840	34	414	300,000	14,700	196	2,300	1,670,000	2,049,000
Mean annual flow for 7-year period			220	159,680			890	560,710			3,039	2,208,550	2,928,940

TABLE 14.

Flow of water in San Joaquin River Basin, October, 1907, to September 30, 1911.

Stream	Drainage area square miles	Maximum flood flow second-feet	Maximum mean daily flow second-feet	Maximum monthly flow acre-feet	Minimum monthly flow acre-feet	Maximum annual flow acre-feet	Minimum annual flow acre-feet	Mean annual flow acre-feet
San Joaquin	1,640	38,800	38,800	946,000	16,200	3,560,000	1,140,000	2,410,000
Merced	1,090	37,200	37,200	465,000	4,140	2,120,000	518,000	1,314,500
Tuolumne	1,500	52,600	52,500	821,000	6,900	3,410,000	1,070,000	2,295,000
Stanislaus	935	36,900	36,900	491,000	6,960	2,320,000	593,000	1,543,250
Calaveras	395	69,600	69,600	323,000		675,000	67,200	354,300
Mokelumne	642	16,700	16,700	331,000	3,960	1,530,000	480,000	1,016,500
Cosumnes	524	22,400	22,400	26,400		874,000	148,000	530,750
	6,726	274,200				14,489,000		9,464,300

TABLE 15.

Annual flow of the San Joaquin and tributaries.

(Expressed in acre-feet for each year, 1907-08 to 1911-12.)

	1907-8	1908-9	1909-10	1910-11	1911-12
San Joaquin	1,140,000	2,900,000	2,040,000	3,560,000	906,000
Merced	518,000	1,480,000	1,140,000	2,120,000	----------
Tuolumne	1,070,000	2,650,000	2,080,000	3,410,000	966,000
Stanislaus	593,000	1,890,000	1,370,000	2,320,000	534,000
Calaveras	*67,200	472,000	195,000	675,000	130,000
Mokelumne	480,000	1,150,000	906,000	1,530,000	371,000
Cosumnes	148,000	638,000	463,000	8,745,000	122,000

*Record incomplete.

NOTE.—The period 1911-12 ends June 30, 1912, being three months short of the year.

A study of the tables of stream flow herein presented reveals the fact that years of greatest flood-flows are not necessarily the wettest years or years of greatest run-off.

Also the years of greatest flow in one drainage basin is not always coincident with the greatest run-off in adjacent areas.

WATER POWERS.

The foregoing discussion of the flow of water into the Sacramento and San Joaquin valleys is based upon measurements taken at the edge of the valleys and is considered only with relation to the uses of the water for irrigation and navigation and to the prevention of injury resulting from floods.

It has been explained that because these were the only subjects formerly considered, the most of the research was confined to the lower reaches of the rivers. Some measurements were occasionally made, and a few gaging stations were established back toward the headwaters of the streams, particularly in the vicinity of likely sites for reservoirs.

But with the astonishingly rapid extension of the employment of the silent force of electricity in every branch of industrial activity and the equally wonderful improvements in the methods of the transmutation of this invisible, mysterious force from the latent potentiality of the rushing, leaping, tumbling mountain torrent hurrying down its rocky way to the sea, comes an urgent need for inquiry to learn where and to what extent hydroelectric development might be available.

The increased amount of funds obtained by cooperation between the state and the United States enabled a large extension to be made in the field of operations; more extensive research was conducted and more complete data obtained.

The records compiled show that the waters of the State of California are capable of producing a vast amount of power. The present

and prospective use of power has induced capital to install some wonderful plants among the hills of the state, and the development has been so rapid that California now stands second among the states in the amount of power developed from water.

At the close of the statistical year in 1908, California had 559 installations operating 1,070 wheels which were capable of producing 466,774 horsepower. New York was the only state which could show a larger production. Including nearly 200,000 horsepower produced at Niagara with 6,513 wheels operating in 3,148 plants produced a total of 885,862 horsepower, while in Maine the output of the state was 343,096 horsepower developed by 2,797 wheels installed in 1,222 plants.

The total water power developed in the United States is placed at 5,356,680 horsepower.

Arranged in tabular form the foregoing figures appear thus:

TABLE 16.

State	No. plants	No. wheels	Total horsepower	Unit capacity
New York	3,148	6,513	885,862	136
California	559	1,070	466,774	436
Maine	1,222	2,797	343,096	123
United States	31,537	52,827	5,356,680	101

A comparison of the unit capacity of the plants in California and in Maine is interesting; the former producing 436 horsepower to the wheel, while the latter was only getting 123 horsepower from each wheel turned. This is explained as being due to the fact that the eastern plants are operated with low heads, while the precipitous slopes and high altitudes of the California mountains enable enormous pressures to be used. Several plants for generating electricity in the state are operated under heads exceeding 1,600 feet.

California's 1,070 wheels are distributed to every portion of the state. The following table gives their distribution in the several drainage areas, and the power they produce.

TABLE 17.

Drainage area	No. of wheels	Horsepower produced
Sacramento River	576	280,735
San Joaquin River	159	86,224
San Francisco Bay region	11	6,455
Southwest coast	74	50,183
Northwest coast	176	25,440
Eastern Sierra slope	74	17,737

The above are figures from a compilation by the United States Bureau of the Census, published in papers presented by members of

the Geological Survey, for the report of the National Conservation Commission (S. Doc. 676, 60th Cong., 2d Sess.) and reprinted in Water Supply Paper No. 234, of the United States Geological Survey.

Since those statistics were published several new hydroelectric units have been completed or construction begun, aggregating many thousands of horsepower.

The foregoing estimates relate to water powers already developed, but it is the *undeveloped* powers which concern the people of California. The power which has been developed is owned as property in fee for all time by the parties who own wheels, but not quite so with all of the undeveloped power.

Until the Water Power Commission was created in 1911 the laws of California gave, without recompense, to whoever would take it, the energy that resides in the streams of the state. Capital, seeking investment, discovered this hitherto unrecognized source of wealth and proceeded to acquire possession of it.

Happily the spoliation of the people's interest in this great natural resource was arrested by action of a patriotic legislature, before it had all been secured by private interests, as that session enacted a statute prescribing finite limits to the use of the public's water powers for private aggrandizement.

Since the state has assumed, or rather *resumed,* its right to regulate the taking and using of its waters for producing power it should acquire complete and accurate information as to the amount of power available and the location of its source; and to enable it to meet its obligations in this regard special effort has been made to extend the research conducted by the Geological Survey in cooperation with the state.

In the report of this department for 1910 a list of gaging stations then being maintained was published, showing the location of 69 stations, distributed throughout all of the drainage areas of the state excepting the northwest coast. A few measurements were made in that region during the summer of 1910 and the hope was expressed that the field operations could soon be extended to cover Russian, Klamath and intervening watersheds. During the biennial period 1911-12, thirty-four stations for observation were established in that territory.

The cooperative spirit is growing among governmental bodies, and of recent years the research conducted by the Survey has been assisted greatly by cooperation with the Forest Service in getting volunteer observers for distant points in the persons of the forest rangers.

With the organization three years ago of the State Water Commission and the State Conservation Commission—additional bodies bent upon acquiring the same kind of data that was already being col-

lected—it seemed as though much effort might be dissipated in duplicating that which had already been accomplished. But by combining the funds of all the bodies concerned, the Survey was enabled to extend its activities greatly.

In addition to the cooperative arrangement between the Survey and the Department of Engineering and the two commissions above mentioned by which a very great amount of data was secured in 1912–13, similar cooperation was effected with the city of Los Angeles for extensive work in Owens River; with the city of San Francisco for continuous observations at several points in the Tuolumne watershed.

Of the sixty-nine stations enumerated in the report of 1910, there were twenty-nine discontinued during 1911–12, but 162 new ones were added. These 202 remaining were described in the report published in 1912.

Since that date there have been sixty-five stations abolished and forty-six established, leaving 183 stations in operation at the end of the fiscal year, June 30, 1914. A complete list of these stations, with those discontinued indicated, will be found in the report of the district engineer in charge of cooperative work at the end of this article.

The extension of the field of observation by the establishing of more numerous gaging stations in the mountains, is enabling the gathering and verifying of much data as to the potentiality of the streams of the state. Observations are not made at enough points, nor have they been conducted over a sufficiently long period of time, to enable close estimates, but the indications are that the figures heretofore quoted may be verified.

The report of this Department two years ago gave a short description of the drainage basins and their physical characteristics of the main streams tributary to the Sacramento and San Joaquin valleys. A summary of the power capacities assigned to those streams as possible of development is as follows:

TABLE 18.

Drainage basin	Power possibilities without storage. Horsepower	Power with complete storage. Horsepower
Sacramento	2,000,000	3,000,000
San Joaquin	600,000	1,500,000
Other streams	900,000	1,500,000
Totals	3,500,000	6,000,000

Investigations into the water resources of the state by the United States Geological Survey in cooperation with the State of California since the last biennial report have been conducted under the charge

of Mr. M. O. Leighton, chief hydrographer until June 3, 1913, when Mr. N. C. Grover succeeded to the position with the title of Chief Hydraulic Engineer, Chief of the Water Resources Branch, United States Geological Survey, and Mr. J. C. Hoyt, Hydraulic Engineer in charge of Surface Water Division, by Mr. H. D. McGlashan, district engineer.

Their report here follows:

UNITED STATES GEOLOGICAL SURVEY, WATER RESOURCES BRANCH, IN COOPERATION WITH THE STATE OF CALIFORNIA.

Progress Report of Surface Water Investigations by the Water Resources Branch, U. S. Geological Survey for 1912-14.

By N. C. Grover, Chief Hydraulic Engineer, and H. D. McGlashan, District Engineer.

The work of the Water Resources Branch of the United States Geological Survey in California during the past two years has been largely a continuation of that reported two years ago. The cooperative funds furnished by the Conservation Commission and the Water Commission permitted this marked increase in the work of this district, beginning in August, 1911. In August, 1913, on account of the reduction in these funds, it was necessary to discontinue forty gaging stations. It has also been necessary to abandon a number of Forest Service cooperative stations during the past two years, on account of the inability of the rangers to furnish the necessary gage height observations. The following table gives the gaging stations maintained during the two-year period ending November, 1914. The * indicates that the station is now not in operation on account of lack of funds or unfavorable conditions for accurate results.

TABLE 19.

Stream	Postoffice
American River	Fairoaks.
American River (Middle Fork)	East Auburn.
American River (South Fork)	Placerville.
American River (North Fork)	Colfax.
Arroyo Seco	Soledad.
Arroyo Seco	Pasadena.
*Basin Creek	Havilah.
*Bear Creek	Millville.
Bear Creek	Springville.
Bear River	Van Trent.
Bear River	Colfax.
Bear River power canal	Colfax.
*Big Creek	Wawona.
Big Creek	Shaver.
Big Creek	Tollhouse.
Boulder Creek (mouth)	Lakeside.
Boulder Creek (Cuyamaca Reservoir)	Lakeside.
Buckeye Creek	Bridgeport.
*Burney Creek	Burney.
Butt Creek	Butte Valley.
Cache Creek	Lower Lake.
Cache Creek	Yolo.
Calaveras River	Jenny Lind.
Carson River (West Fork)	Woodfords.
Carson River (East Fork)	Markleeville.
Cherry Creek	Sequoia.
Clavey River	Tuolumne.
Clear Lake	Lakeport.
Clear Creek	Shasta.
*Clover Creek	Millville.
*Coffee Creek	Coffee.
*Corral Creek	Groveland.
Cosumnes River	Michigan Bar.

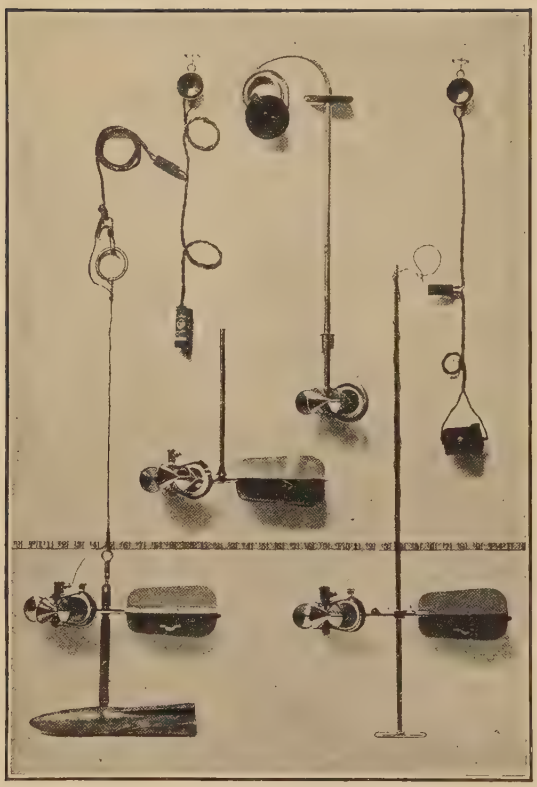
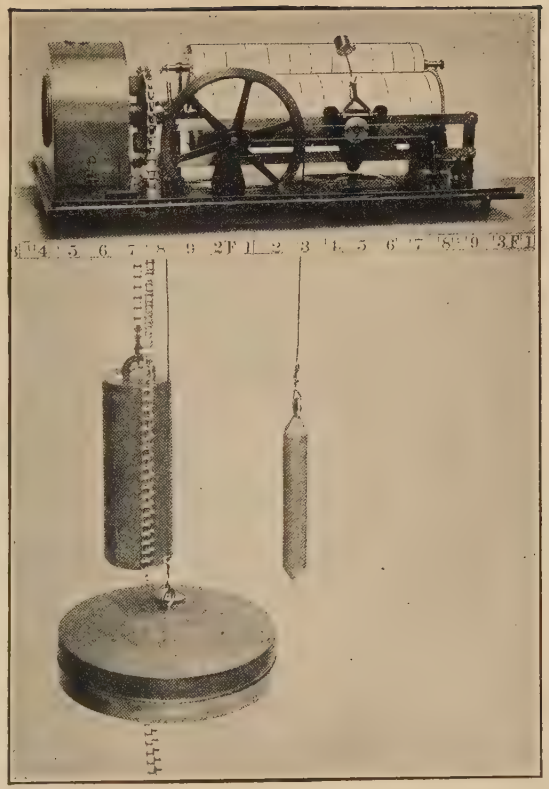
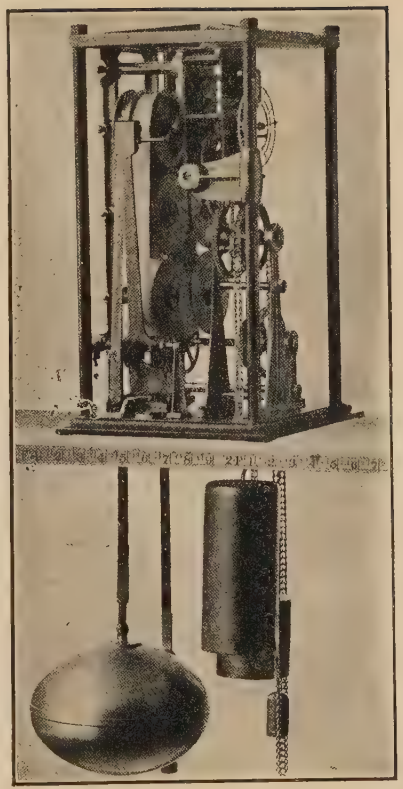


Plate XXVI. Instruments Used in Stream Measurements.

The Price Current Meter. These little instruments, when lowered into running water, turn with the current, the speed depending upon the velocity of the current. The number of revolutions in a given time is indicated by suitable apparatus and the current velocity deducted therefrom. These illustrations are furnished by the United States Geological Survey.





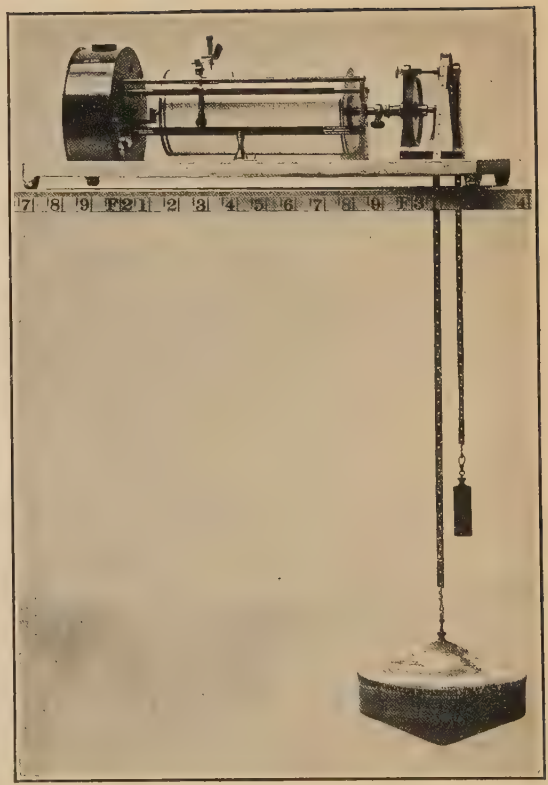


Plate XXVII. Instruments for Recording Gage Heights.

TABLE 19—Continued.

Stream	Postoffice
Cosumnes River (North Fork)	El Dorado.
Cottonwood Creek	Dulzura.
*Cottonwood Creek (North Fork)	Ono.
*Cow Creek	Millville.
Crane Valley Reservoir	North Fork.
Deer Creek	Hot Springs.
Deer Creek	Vina.
*Devil Canyon Creek	San Bernardino.
Dinkey Creek	Ockenden.
Donner Creek	Truckee.
*East Carson River (Silver King Valley)	Markleeville.
East Walker River	Bridgeport.
*Eel River	Laytonville.
Eel River	Scotia.
*Eel River (South Fork)	Garberville.
Eleanor Creek	Sequoia.
Erskine Creek	Bodfish.
*Fall River	Fall River Mills.
Feather River	Oroville.
Feather River (Middle Fork)	Oroville.
Feather River (Middle Fork)	Cromberg.
Feather River (North Fork)	Prattville.
Feather River (North Fork) Big Bar near	Oroville.
Feather River (South Fork)	Enterprise.
*Fresno River	Knowles.
*Fresno River (North Fork)	Sugar Pine.
Golden Rock Ditch	Sequoia.
Goodyear Creek	Goodyear Bar.
Hat Creek	Hat Creek.
*Hat Creek (Hawkins Ranch)	Hat Creek.
*Hunter Creek	Tuolumne.
Indian Creek	Crescent Mills.
Indian Creek	Happy Camp.
Jawbone Creek	Tuolumne.
Kaweah River	Three Rivers.
Kaweah River (North Fork) at	Kaweah.
Kaweah River (South Fork)	Three Rivers.
Kaweah River (East Fork)	Hammond.
Kaweah River (Marble Fork)	Ranger.
Kaweah River (Middle Fork)	Hammond.
Kaweah River (North Fork) near	Kaweah.
Kern River	Bakersfield.
*Kern River	Isabella.
Kern River	Kernville.
*Kern River (South Fork)	Isabella.
*Kern River (South Fork)	Onyx.
Kern River power canal	Isabella.
Kings River	Sanger.
*Klamath River	Happy Camp.
Klamath River	Requa.
Kings River (North Fork)	Ockenden.
Klamath River	Sciad Valley.
*Knight Creek	Jupiter.
Kosk Creek	Henderson.
Lake Tahoe	Tahoe.
Leevining Creek	Mono Lake.
*Little Cow Creek	Palo Cedro.
*Little Stony Creek	Lodoga.
Little Truckee River	Boca.
Lytle Creek	San Bernardino.
*Mad River	Arcata.
Markleeville Creek above	Markleeville.
Markleeville Creek at	Markleeville.
Matagual Creek	Warner Springs.
*Mattole River	Petrolia.
McCloud River	Baird.
Merced River	Merced Falls.
*Merced River	Newman.
Merced River	Yosemite.
Merced River (South Fork)	Wawona.
Middle Eel River	Covelo.

TABLE 19—Continued.

Stream	Postoffice
*Mill Creek	Los Molinos.
Mill Creek	Forest Home.
Modesto Canal	Lagrange.
Mokelumne River	Clements.
Mokelumne River (Licking Fork)	Railroad Flat.
Mokelumne River (Middle Fork)	West Point.
Mokelumne River (South Fork)	Railroad Flat.
Mono Lake	Mono Lake.
*Montgomery Creek	Montgomery Creek.
*Nelder Creek	Fresno Flats.
Oakdale Canal	Knights Ferry.
Oregon Creek	North San Juan.
Owens River	Lone Pine.
Owens River	Round Valley.
Owens River	Tinemaha.
Owens Lake	Olancha.
Pacific Light and Power Company's canal	Azusa.
*Pajaro River	Watsonville.
Pacific Light and Power Company's canal	Mentone.
Palermo Land and Water Company's canal	Enterprise.
Pine Creek	Round Valley.
*Piru Creek	Piru.
Pit River	Henderson.
Pit River	Ydalpom.
Pitman Creek	Shaver.
*Prosser Creek	Truckee.
Putah Creek	Winters.
*Redwood Creek	Korbel.
*Redwood Creek	Orick.
Reeve-Davis Consolidated Mining Company flume	Happy Camp.
Relief Creek	Avery.
*Rising River	Cassel.
Robinson Creek	Bridgeport.
Rock Creek	Goodyear Bar.
Rock Creek	Round Valley.
*Rose Creek	Jupiter.
Rush Creek	Mono Lake.
*Rush Creek	Ockenden.
*Russian River	Geyserville.
*Russian River	Ukiah.
*Russian River (East Fork)	Ukiah.
Sacramento River	Castella.
*Sacramento River	Grafton.
Sacramento River	Red Bluff.
Salmon River	Somesbar.
Salton Sea	Salton.
San Antonia Creek	Upland.
San Diego River	Lakeside.
San Diego flume	Lakeside.
San Diego River	San Diego.
San Diego River	Santee.
San Diego River (at diverting dam)	Lakeside.
San Diego flume (at diverting dam)	Lakeside.
San Diego River (South Fork)	Alpine.
San Diego River (South Fork) flume	Alpine.
San Dieguito River	Bernardo.
San Dieguito River	Del Mar.
San Gabriel River	Azusa.
San Gabriel River (headworks)	Azusa.
San Joaquin River	Friant.
San Joaquin River	Newman.
San Joaquin River	North Fork.
San Luis Rey River	Bonsall.
San Luis Rey River	Mesa Grande.
San Luis Rey River	Oceanside.
San Luis Rey River	Pala.
San Luis Rey River	Warner Springs.
San Luis Rey River (West Fork)	Warner Springs.
Santa Ana River	Mentone.
Santa Maria River	Ramona.
*Santa Paula Creek	Santa Paula.

Plate XXVIII—A. For Bridge Measurement.

B. For Wading Measurement.

TYPICAL GAGING STATIONS.

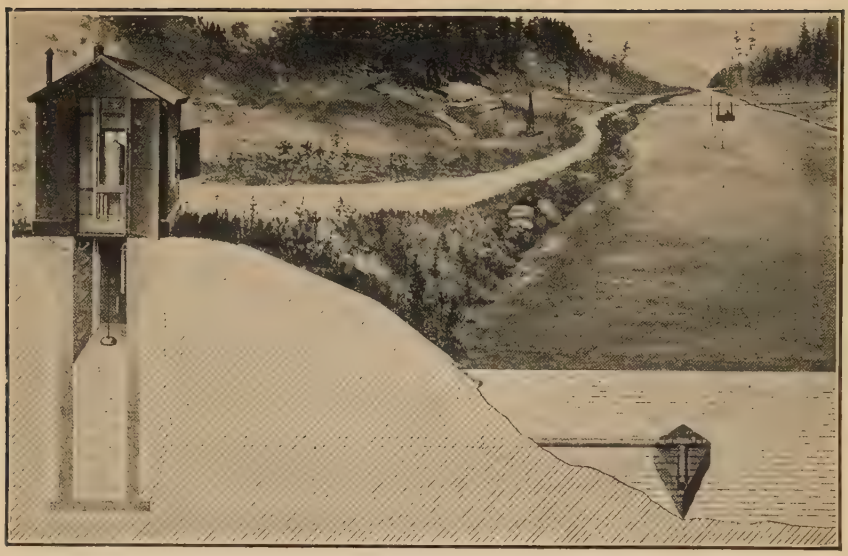


Plate XXIX—A. Typical Gaging Station With Well and Register Housed.

Stream Measurements. The meter is lowered into the water from a convenient bridge, from a cage suspended on a cable, as above, or in shallow water by the observer wading. Automatic registers, which record the rise and fall of the stream are frequently installed, and these instruments are protected by housings of concrete or lumber, or combinations of both, as shown in plates.

B Concrete Housing Over Gage Register

TABLE 19—Continued.

Stream	Postoffice
Santa Ynez River	Lompoc.
Santa Ynez River	Santa Barbara.
Santa Ynez River	Solvang.
Santa Ysabel Creek	Ramona.
Santa Ysabel Creek	Mesa Grande.
Santa Ysabel Creek	Santa Ysabel.
Scott River	Callahan.
*Scott River	Scott Bar.
Scott River (East Fork)	Callahan.
*Sespe Creek	Sespe.
*Shasta River	Montague.
*Silver Creek	Markleeville.
Smith River (Middle Fork)	Crescent City.
Smith River (North Fork)	Crescent City.
*Smith River (South Fork)	Crescent City.
South Fork Creek	North Fork.
*South Eel River	Hearst.
South San Joaquin canal	Knights Ferry.
Spanish Creek	Keddie.
*Squaw Creek	Ydalpom.
Stanislaus River	Knights Ferry.
Stanislaus River (Middle Fork)	Avery.
Stanislaus River (North Fork)	Avery.
*Stanislaus Water Company's canal	Knights Ferry.
*Stanislaus River (South Fork)	Columbia.
*Stanislaus River (South Fork)	Confidence.
*Stony Creek	Fruto.
Swager Creek	Bridgeport.
Sweetwater River	Dehesa.
Sweetwater River	Descanso.
Swift Creek	Trinity Center.
Tenaya Creek	Yosemite.
Trinity River	Hoopa.
Trinity River	Lewiston.
Trinity River	Trinity Center.
*Trinity River	China Flat.
*Trinity River (South Fork)	China Flat.
Trinity River (East Fork)	Trinity Center.
*Trinity River (North Fork)	Helena.
Truckee River	Iceland.
Truckee River	Tahoe.
Tulare Lake	Stratford.
Tule River	Porterville.
Tule River (South Fork)	Porterville.
Tule River (North Fork of Middle Fork)	Springville.
Tule River (South Fork of Middle Fork)	Springville.
Tuolumne River	Lagrange.
Tuolumne River (Hetch Hetchy dam site)	Sequoia.
Tuolumne River (Hetch Hetchy cabin)	Sequoia.
*Tuolumne River (North Fork)	Tuolumne.
Tuolumne River	Groveland.
Tuolumne River (South Fork)	Groveland.
Tuolumne River (South Fork)	Sequoia.
Turlock Canal	Lagrange.
*Tyler Creek	Hot Springs.
Utica Gold Mining Company's canal	Avery.
*Van Duzen River	Bridgeville.
Ventura River	Nordhoff.
*Ventura River	Ventura.
*Waterman Canyon Creek	San Bernardino.
West San Pasqual Ditch	Escondido.
Whiskey Creek	North Fork.
*White River	Hot Springs.
*Yager Creek	Carlotta.
Yosemite Creek	Yosemite.
Yosemite Power Company's canal	Lagrange.
Yuba River	Smartsville.
Yuba River (Middle Fork)	North San Juan.
Yuba River (North Fork)	Goodyear Bar.
*Yuba River (North Fork)	Sierra City.
Yuba River (North Fork of North Fork)	Downieville.

The equipment at the gaging stations has been greatly improved during the past two years by the installation of new gaging cars, recording gages, and improved staff gages. An important feature of the work has been the installation of twelve recording gages, distributed equally in the three major drainage basins of the State, viz: Sacramento, San Joaquin, and South Pacific.

These instruments are very necessary on streams which have a considerable diurnal fluctuation or are subject to sudden and severe floods; also at locations where regular and reliable gage observers can not be secured at a reasonable cost.

Two types of recording gage are in use in this district—the Friez which furnishes a seven-day record traced upon a special sheet of cross section paper, and the Gurley which stamps the gage readings on a paper ribbon every fifteen minutes. The latter gage operates for several weeks without attention.

The essential features of these installations are a gage house to protect the instrument from the weather, a float well which supports the gage house, and an intake pipe which connects the stream with the well in order that the elevation of the water surface in the well may be the same as that of the stream. As a rule the gage house is built of wood and the well lined with timber. At exposed locations reinforced concrete has been used in order to afford the necessary protection from floods. This is a permanent and very satisfactory type of installation.

The natural conditions in southern California are very unfortunate for securing accurate stream flow records. The streams have heavy grades and are subject to excessive floods which result in marked changes in channel. For the most part the stream beds are composed of sand or gravel and are very unstable at all stages. In order to eliminate this shifting of channel, artificial controls have been installed at several of our gaging stations. They consist usually of a concrete cut-off wall extending across the channel just below the gage. The object of these controls is to make the gage readings a correct index of the discharge. These experiments have proved very satisfactory and have greatly increased the accuracy of our records.

At the request of the city of San Francisco, this office, on May 1, 1914, took charge of all their stream gaging work in connection with the Hetch Hetchy project. The plans are to measure the inflow and outflow at each of the proposed reservoir sites. A large amount of very valuable and interesting data will be collected on Tuolumne River and tributaries. This work is maintained in cooperation with M. M. O'Shaughnessy, city engineer, and all expenses are paid directly by the city of San Francisco.

In the administration of the work the Survey maintains the district office at 328 Custom House, San Francisco. A suboffice is maintained at 619 Federal Building, Los Angeles, for the benefit of that portion of the state.

No surface water supply papers for California have been published since your last report. Papers 330 and 331 are now in press and are expected to be available for distribution in a short time.

UNDERGROUND WATER SUPPLY.

Contemporaneously with the inquiry into conditions affecting the flow of surface streams, investigations are being made by the hydrographic branch of the United States Geological Survey in cooperation with the state relating to underground waters.

The 45,000,000 acre-feet of water which the streams of California annually discharge into the sea and inland lakes, or lose in the porous soils of the plains, would be more than enough to irrigate all of the *14,000,000 acres of irrigable lands in the state, if it could be conserved so as to be applied to the land when needed and in manner and quantity required. But that, for various reasons, is manifestly impossible.

*Estimates by Prof. Hilgard and Prof. Loughridge, University of California.

A. Concrete Well.

B. Wooden Register House.

C. Lumber Register House.

Plate XXX. STREAM GAGING. TYPICAL HOUSINGS FOR GAGE REGISTERS.

(Courtesy U. S. Geological Survey.)

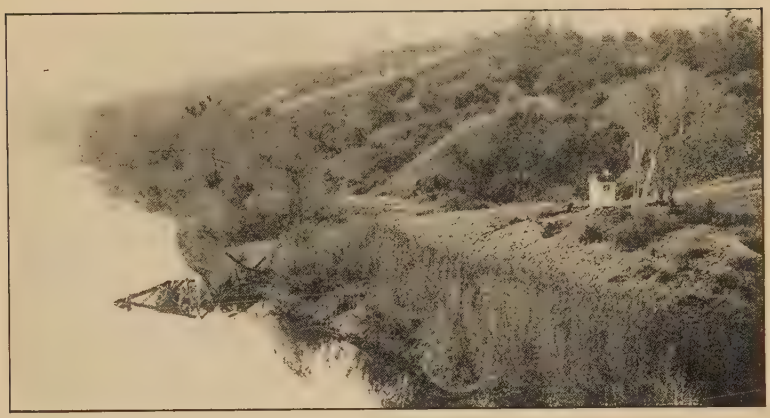


Plate XXXI—A. Gage House, Feather River, Near Oroville.

B. Stream Gaging, Artificial Control. (Courtesy U. S. Geological Survey.)
When the beds of small streams are uneven, concrete sills or weirs are frequently installed.

Many of the streams—those along the northwest coast, for instance—are in regions where little or no irrigation is required, and impassable ranges of mountains bar the way to taking the water to lands needing it.

The Great Valley, embracing Sacramento and San Joaquin valleys, contains more than 10,000,000 acres of arable land, most of it benefited by irrigation, and a large part unproductive without water. The streams of this region discharge more than 37,000,000 acre-feet of water into the sea annually; because of the lack of storage possibilities most of it must ever continue to flow into the ocean. Much of the rainfall is absorbed by the soil upon which it falls and does not contribute to the visible runoff.

In southern California, where water is extremely limited in quantity and has a high agricultural value, exploration for underground sources and their development has been extensive. The high order of intelligence of the people engaged in husbandry here has enabled scientific methods to be applied, and the conservation and economical use of water for irrigation has reached a degree of refinement not surpassed anywhere else in the world.

Responding to the need for systematic study by trained minds of the conditions that would indicate the probable location and extent of underground sources of water, and matters affecting its recovery and application, this research has been prosecuted.

The first field of investigation after cooperation was established between the government and the state, was in the foothill belt of southern California (published in Water Supply Paper No. 219) followed by examinations in San Joaquin Valley, reported in Water Supply Paper No. 222. In 1909 a report was made in Paper No. 225, of research made in a portion of the Mojave Desert known as Coachella Valley. Other papers describe results of investigations made elsewhere. The inquiry into the many phases of conservation of natural resources enjoined upon the Conservation Commission led to an agreement of cooperation between the Commission and the Survey in 1912, which enabled the latter to greatly extend its activities. Also cooperation with the administration of the Los Angeles aqueduct enabled an intensive study to be made of the ground storage of waters in Owens Valley, which has been published as Water Supply Paper 294.

Studies of ground waters in the San Joaquin Valley have been concluded, and the results will shortly appear in a water supply paper. Studies of pumping in the San Joaquin Valley as a means of irrigation are in progress.

The paper promised in the last report treating of the mineral and hot springs of California has been completed and will soon be off the press.

Investigations of underground waters in the Santa Clara Valley and of Sacramento Valley have continued. The observations conducted in the vicinity of Los Angeles and San Bernardino for several years are still being made. Much of the data will soon be published.

A close study of ground waters in connection with observations of surface run-off in several southern regions is being made in the interests of municipal domestic water supply, notably in the San Diego watersheds.

The cooperative investigations in this subject during the two years ending June 30, 1914, were conducted under the direction of Mr. N. C. Grover, chief hydraulic engineer, water resources branch, and Mr. O. E. Meinzer, geologist in charge, ground water divisions, whose report here follows:

UNITED STATES GEOLOGICAL SURVEY, WATER RESOURCES BRANCH, IN COOPERATION WITH THE STATE OF CALIFORNIA.

Progress Report of Underground Water Investigations in the State of California during the years 1913-1914.

By O. E. MEINZER, geologist in charge, ground water division.

The paper of "Springs in California," by G. A. Waring and Herman Stabler, mentioned on page 176 of the Third Biennial Report of the Department of Engineering, State of California, has been at the Government Printing Office for some time. The second page-proof was received November 2, 1914, and the published report will no doubt be ready for distribution in a few weeks. It will be issued as Water Supply Paper No. 338.

The final report on the occurrence and quality of ground water of San Joaquin Valley, by W. C. Mendenhall and R. B. Dole, has been transmitted to the Director of the Geological Survey for publication as a water-supply paper. In this report the subject of the mineral quality of the ground water, with special reference to its use for irrigation, is exhaustively treated by Mr. Dole. The practicability of utilizing the more highly mineralized waters on the west side of the valley and the prospects of obtaining better water at greater depths have been investigated and are discussed in the report.

The report on pumping in the San Joaquin Valley, by Herman Stabler, is nearly complete. The completion of the San Joaquin reports has been delayed by the heavy duties thrust upon Messrs. Mendenhall and Stabler in connection with the land classification work of the survey.

An extensive study of the ground water of the Niles cone, supplied by Alameda Creek, on the east side of San Francisco Bay, has been prosecuted during the years 1912, 1913 and 1914 by W. O. Clark of the U. S. Geological Survey. The ground-water problems in this drainage basin are especially acute because of the diversions that are made by the Spring Valley Water Company and the Peoples Water Company for the municipal supplies of San Francisco and the transbay cities, and because of the extension of irrigation depending on underground sources. For many years there has been litigation between the various water users, and more is in prospect. The questions as to the area depending on water supplied by Alameda Creek and the available quantity of ground water have long been disputed. The report which was submitted by Mr. Clark and which is now in press, furnishes reliable and conclusive evidence bearing on these questions. This report will be issued by the U. S. Geological Survey as Water Supply Paper 345–H.

An investigation of the entire Santa Clara Valley has been carried on since August, 1912, by W. O. Clark simultaneously with the intensive study of the Niles

cone, which is situated in this valley. Complete information on irrigation with ground water is being obtained, and maps are being prepared similar to those made by Mr. Mendenhall in southern California.

While this general survey of the valley as a whole is in progress, special attention is being given to the vicinity of Coyote, where there has been litigation between the local irrigators and the Bay Cities Water Company. The studies in this vicinity will be conducted along lines similar to those on the Niles cone. About 500 wells are under observation and the depth to the water level in each is measured monthly or weekly.

A thorough investigation of the ground water of the Sacramento Valley south of Red Bluff has been in progress continuously since September, 1912. The work has been carried on by Kirk Bryan of the U. S. Geological Survey, assisted in 1914 by J. W. Muller, also of the survey. The important developments in irrigation with ground water in this valley during the last few years and the favorable ground water conditions make this investigation one of great importance. Complete data have been obtained as to wells and pumping plants used for irrigation, and all tracts irrigated with ground water, aggregating about 40,000 acres, have been mapped. A preliminary report, prepared by Mr. Bryan, will be sent to the Government Printing Office in a few days, and will be published as a water supply paper of the Geological Survey. The final report, which will be published as soon as possible, will be a comprehensive paper dealing in detail with all phases of the subject. It will contain a series of detailed maps and other illustrations, and also much practical advice for prospective irrigators.

In September, 1914, an investigation of the ground water of San Diego County west of the divide was begun. This investigation is being conducted by A. J. Ellis, geologist of the U. S. Geological Survey, and Charles H. Lee, hydraulic engineer, whose investigations in the Owens Valley (see Water Supply Paper 294), in the Indian Springs Valley, and on the subject of water conservation by spreading of floods (see report of the State Conservation Commission for 1912) are a guarantee of thorough work. The city of San Diego, which is vitally concerned in the water resources of this area, is cooperating financially with the U. S. Geological Survey and the State Department of Engineering in this investigation. The investigation is planned on a comprehensive basis. It will cover questions of deep water horizons, quantities stored in the valley fill, the storage capacity of the fill, etc. The ground-water work is closely coordinated with the extensive surface water investigations that have for several years been made in the county by F. C. Ebert, under the direction of H. D. McGlashan, both of the U. S. Geological Survey, and a complete report on the water resources of the county west of the divide is contemplated.

Periodic measurements of water levels and typical wells on the coastal plain west of Los Angeles, in the foothill belt east of the city, and in the San Bernardino and other valleys of southern California, were begun by W. C. Mendenhall in 1904 for the purpose of obtaining a record of water-table fluctuations and the resulting information on the relations of ground-water recharge to ground-water withdrawals. These measurements have been continued with some interruptions since 1904. During the last biennial period the work has been in charge of Mr. Ebert. The data for several years are being published in Water Supply Paper 331, and Mr. Ebert is also preparing as a separate report a compilation of all well-gage records for this area.

IRRIGATION INQUIRY.

By authority of an act of the legislature passed in 1905 the State Board of Examiners entered into an agreement with the Director of the Office of the Experiment Stations, United States Department of Agriculture, for the prosecution of a line of inquiry relating to irrigation.

The inquiry embraced the following:

(*a*) The duty of water and the factors which influence it.

(*b*) Methods of irrigation employed in California with a view of securing better practice.

(*c*) Best methods of organizing communities and districts so as to secure stable supply and equitable and economical distribution of the water to users.

(*d*) Methods and costs of pumping.

(*e*) Loss from canals through seepage, evaporation and wasteful methods, and the best means of reducing the same.

(*f*) Drainage problem.

Upon the organization of the Department of Engineering in 1907, the State Engineer succeeded the Board of Examiners as the representative of the State in agreements for cooperative work with the several branches of the Government with which cooperative relations are maintained.

In the report of this department for 1908 the chaotic condition of the laws of California relating to water rights was pointed out and the need of reformation of such laws was discussed. Following up the ideas there promulgated, when the cooperation agreement was renewed for the year 1909–10, it was provided that the inquiry should include a new subject, to wit:

(*g*) Methods of establishing and protecting rights to water and their effect on the best utilization of the water resources of the state.

Investigations under the first topic, duty of water, were first confined to attempts to determine the amount of water being used by irrigators in producing various crops in different localities, but in some cases the difficulty of getting correct measurements and the excessively wasteful methods of application gave results of but little value.

Later, records of the use of water were obtained from commercial irrigating companies which were more reliable. In cooperation with the University of California, experiments were made at the University Farm at Davis under conditions created for the purpose, so that the results give more exact information. Cooperation was effected with the Turlock Irrigation District and with farmers and orchardists in different sections, so that the field of observations has included many of the actual conditions confronting the irrigator, and the results obtained should be of practical benefit.

The extended field covering the investigations into the duty of water afforded greater opportunity for the study of methods of irrigation as well. The question of organization of communities has been exhaustively studied. Methods and costs of pumping have received careful attention and much valuable information has been obtained. Losses of

water in transit from source to orchard or field has been studied, as well as the drainage problem in connection with irrigation.

Research in the last topic, methods of establishing and protecting rights to water, etc., supported by the advocacy of this department for some means of settling water rights, contributed to the influences which brought about the creation of the Conservation Commission and the Water Power Commission. These commissions joined in the cooperative investigations, and thus made possible a broader and more thorough inquiry into these matters.

The resulting consensus of the work of these several agencies had much to do with the creation by the legislature in 1913 of a Water Commission under whose administration it is hoped and believed that order will be brought out of the present chaotic condition of water rights in this state.

Closer relations have been effected between the Office of Experiment Stations and the University of California, which has greatly assisted in all of the cooperative investigations.

During the last biennial period the studies of the subject of the duty of water has been continued along the lines described in the report two years ago, but with some important additions, notably observations in the rice fields, and on private fields of alfalfa and grain throughout the valley, and of orchards, beets and other crops.

Another feature of the irrigation inquiry pursued during this biennial period has been with the purpose of determining the proportion of total annual irrigation required for any subdivision of the year, concerning which practically no information has been published, and yet it is a matter that the Department of Engineering has felt a great need for in making investigations of irrigation district projects for the bond commission. It is not sufficient to know that a tract of land will require irrigation to a certain depth, but it is requisite to know how much of the total amount will be required each month. In the investigations made for the bond commission above referred to it was found that in some localities only 2 per cent of the annual supply of water was required in some months while in others nearly 40 per cent was used. Of course the monthly percentages vary in different localities according to climate, soil, crops and other varying conditions. To become authentic the data concerning this subject must be obtained over a long series of years, but that presented in this report is commended as a beginning in what is conceived to be a branch of research of great importance.

Much study has been given to the matter of land settlement. Experience has shown that raw land, particularly arid land, can not be developed by the ordinary homeseeker. He is usually a man of limited

or no means and it requires time and effort to bring his "homestead" to the productive stage, and while waiting for that time he and his family "must live" or starve.

Several methods of giving aid to the settler have been or are being tried in foreign lands possessing large undeveloped areas. The studies made of this subject will probably be made the subject of bills to be presented at the coming session of the legislature.

The many phases of the great question of irrigation which have been inquired into by the Irrigation Inquiry are two numerous for extended review here and the reader is referred to the very able report here following made by Mr. Frank Adams, irrigation manager in charge:

PROGRESS REPORT OF IRRIGATION INVESTIGATIONS CONDUCTED BY THE OFFICE OF EXPERIMENT STATIONS, UNITED STATES DEPARTMENT OF AGRICULTURE, IN COOPERATION WITH THE STATE OF CALIFORNIA, AND THE UNIVERSITY OF CALIFORNIA AGRICULTURAL EXPERIMENT STATIONS, 1912-1914.

By FRANK ADAMS, irrigation manager, in charge.

There have been no radical changes in the conduct of the cooperative irrigation investigations in California during the biennium ending November 30, 1914. The scope of the work, however, has been somewhat widened through the establishment of a more definite relationship to the University of California Agricultural Experiment Station. While since 1901 the California irrigation investigations of the Office of Experiment Stations have been conducted from office quarters furnished by the College of Agriculture of the University of California, it has only been during the past few years that financial support has been given by the University of California. Not counting an university allotment for irrigation instruction at the University Farm at Davis, the University of California Agricultural Experiment Station is contributing $4,700 to the cooperative fund for the fiscal year 1914–15, in addition to joining in irrigation studies in Imperial Valley (through the division of agronomy) and in studies in orchard irrigation (through the division of pomology) now being started. In place of the former agreements between the Director of the Office of Experiment Stations and the Director of the University of California Agricultural Experiment Station, which have covered participation by the university, equal privileges and responsibilities with those assumed by the Office of Experiment Stations and the California State Department of Engineering are now extended to the University of California Agricultural Experiment Station through tri-party agreement; and subject, of course, to the administrative heads of the cooperating agencies involved, the one in charge of cooperative irrigation investigations in California for the Office of Experiment Stations and the California State Department of Engineering thus definitely becomes charged with responsibility also on behalf of the University of California.

IRRIGATION RESOURCES.

The last of the biennium ending November 30, 1912, was largely devoted to the completion of the studies of irrigation resources of California and their utilization, the expense of which was borne largely by the State Conservation Commission. That study was primarily intended to present a perspective picture of irrigation in California, thereby aiding in the general educational movement aimed toward bringing about the passage of a modern water law for this state. The full reports of the irrigation resources were printed in the report of the State Conservation Commission and a summary of the reports on irrigation resources, together with reports of the use of water on six typical stream systems of the state, were printed in Office of Experiment Stations Bulletin 254, United States Department of Agriculture. Both reports carried the colored irrigation maps of the state that had been prepared to

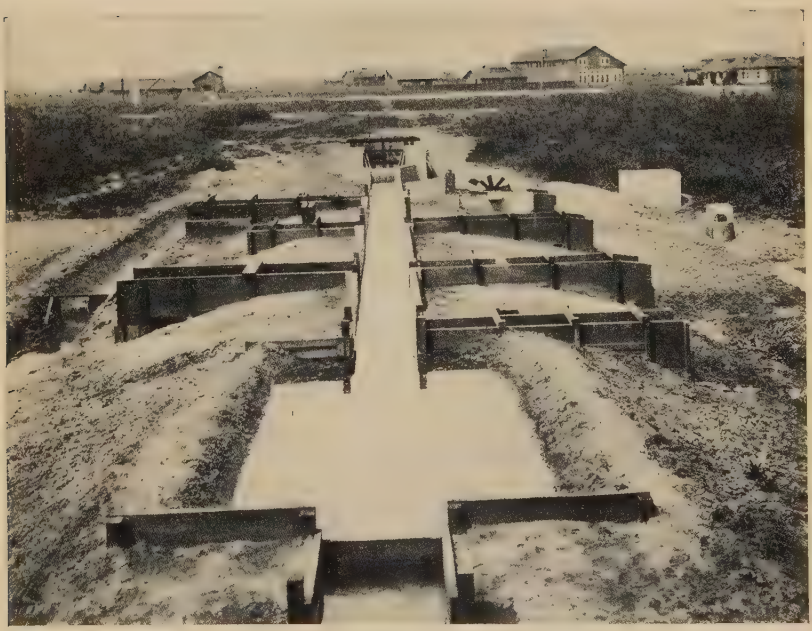


Plate XXXII. Water Measuring Devices, University State Farm, Davis.
(Used in experiments to determine the duty of water.)

accompany them, and Bulletin 254 also carried larger scale irrigation maps, in color, of the six typical stream systems. Four thousand copies of the State Conservation Commission report and 5,000 copies of Office of Experiment Stations Bulletin 254 were issued, both reports having been mainly distributed within California.

IRRIGATION LEGISLATION.

Other than the reports of the irrigation resources of California and of their utilization referred to above, this office has made no special studies of irrigation legislation in California during the past two years. It has, however, cooperated with the State Conservation Commission in making known the purposes of the water commission bill that was presented by the Conservation Commission and passed by the legislature of 1913. In cooperation with the State Association of Irrigation Districts it has also aided in the framing and enactment of amendments to the irrigation district law.

IRRIGATION DISTRICTS.

A special study of California irrigation districts that has been in progress for some years has been completed so far as concerns the districts formed under the original Wright law, and an historical statement regarding each of the old Wright districts has been placed on file in the office of the State Department of Engineering at Sacramento. A summary of all of these statements, which is intended to present in brief form the history of the early irrigation district movement in California, together with statements regarding all existing or proposed California irrigation districts, is now in course of preparation and will be submitted as supplementary to this progress report.

In the fall of 1913 the study of California irrigation districts was extended to include all of the irrigation districts of the western states. Complete field data have been gathered from all of these districts and as soon as they can be worked over they will be prepared for publication in the form of a general report on irrigation districts in the western states and on the operation of the various district laws that those states have enacted.

Belief in the ultimate wide use of the irrigation district form of organization in this state has frequently been expressed by those in charge of irrigation investigations in California and referred to in the previous biennial statements submitted to the Department of Engineering. That this belief has been justified seems clear from the number of new districts that have been formed or proposed during the past two years. The recent amendments to the California irrigation district law have without doubt greatly added to its efficiency, and when the state is given even wider powers than it now possesses in aiding and protecting irrigation districts, increased advantages to the districts and increased protection to holders of irrigation district securities are bound to accrue.

DUTY OF WATER DETERMINATIONS.

During the seasons of 1913 and 1914 the largest single effort has been directed to studies of the duty of water for alfalfa on a large number of farms in Sacramento Valley. These studies have been supplemental to experiments on the duty of water for alfalfa at Davis, that have now been carried through five seasons. It was felt that no matter how conclusive the results of the experiments at Davis might be, a broad basis for conclusions could only be obtained by supplementing the work at Davis with observations on typical farms throughout the valley. In 1913 work was done on 14 farms at Gridley, 9 farms at Los Molinos, 5 farms at Orland, 12 farms at Woodland, and 7 farms at Dixon, a total of 47. The work at Gridley during 1913 disclosed the fact that the ground water there is so close to the surface that observations of the movement of soil moisture applied by irrigation could be of little value. For that reason the Gridley farms were omitted from the studies in 1914. It was also necessary to eliminate the work at Dixon during 1914 on account of lack of funds. It was possible, however, to include Willows in 1914, so that the work during 1914 was carried on as follows: Los Molinos, 11 farms; Orland, 8 farms;

Willows, 6 farms; Woodland, 13 farms; total, 38 farms. Several of the farms at Woodland, Orland, and Los Molinos on which observations were made in 1913 were dropped in 1914 and some others added. This revision was made after the Bureau of Soils of the United States Department of Agriculture and the Division of Soil Technology of the College of Agriculture of the University of California had completed their soil survey of Sacramento Valley and disclosed the prevailing types of soil. Where it was found that important soil types had been omitted in the studies in 1913, several farms having such types were included in 1914. On the other hand, where it was found from the reclassification of the soils that certain types were unnecessarily duplicated, fields with those types that were least favorable for satisfactory results were omitted.

In these studies of the duty of water for alfalfa that have been made on Sacramento Valley farms during the past two years the water applied has been carefully measured by agents of this office and the yields of alfalfa have been ascertained by the same agents in the most practicable manner feasible. In a large number of instances the alfalfa hay has been baled, so that the yields have been ascertained with exactness. In other cases it has been necessary to estimate the yields by measuring the stacks. In other cases still the number of shocks of hay have been counted and a certain number weighed to get the average weight per shock. In a few instances full loads of hay have been hauled to scales. Great care has been exercised in all of the ascertainments of yield and the figures given can be taken as within narrow and reasonable limits of accuracy.

While earlier studies of the duty of water throughout the west have been largely confined merely to measurements of the amounts of water applied, it is now fully recognized that in California at least a point has been reached when studies must be carried sufficiently beyond that point to indicate what becomes of the water applied. Accordingly, determinations of soil moisture in the field have been made before and after each irrigation, on as many fields as the funds available would permit, in all some 15,000 soil moisture determinations having been made during 1914 alone. The method followed has been to make borings with a 3-inch soil auger to depths of 6 feet, with 200-gram samples of soil taken in the center of each foot. In 1914 all of the samples have been forwarded to the laboratory at Davis for moisture determinations. In some cases borings have been made to a depth of 12 feet.

Full field reports of the work on the Sacramento Valley farms during 1913 and 1914 are not yet in, so that a complete statement of results will not be ready for publication until some time during the winter. Tables, however, are given below showing the amounts of water applied and the yields of alfalfa in tons for all of the fields under observation during 1913 and 1914, explanations and discussions of them being withheld for the later publication. In the later discussion the relation of the results on the farms to the results at Davis during the past five years will be fully considered, but pending the complete presentation, those having use for the tables will find profit in comparing the results on the farms away from Davis with those obtained at Davis, which are given in brief elsewhere in this report.

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TABLE 20.

Summary of results of alfalfa duty of water investigations, Gridley, 1913.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
J. W. Humble	NE. ¼ Sec. 6, T. 17 N., R. 3 E.	Silt loam	18.43	4	2.55	5	5.84
T. Baltimore	SE. ¼ Sec. 1, T. 17 N., R. 2 E.	Silt loam	14.93	4	3.42	5	7.20
F. L. Bratton	SW. ¼ Sec. 6, T. 17 N., R. 3 E.	Silt loam	3.29	4	3.82	5	6.83
Chas. Baltimore	SE. ¼ Sec. 1, T. 17 N., R. 2 E.	Silt loam	26.40	5	4.98	5	6.95
W. R. Huartson	SE. ¼ Sec. 5, T. 17 N., R. 3 E.	Silt loam	7.42	4	2.64	5	9.38
C. W. Van Note	NE. ¼ Sec. 17, T. 17 N., R. 3 E.	Clay loam	27.20	5	2.37	5	5.97
W. G. Coppernoll	NE. ¼ Sec. 17, T. 17 N., R. 3 E.	Silt loam	13.96	5	2.83	5	7.28
M. B. Williams	NE. ¼ Sec. 16, T. 17 N., R. 3 E.	Silt loam, clay loam	67.29	4	2.04	5	5.80
A. J. McFarland	NE. ¼ Sec. 16, T. 17 N., R. 3 E.	Silt loam	9.44	5	4.16	5	4.19
John Paulhorn	SE. ¼ Sec. 8, T. 17 N., R. 3 E.	Silt loam	17.10	4	3.93	5	5.88
C. W. Summers	NW. ¼ Sec. 17, T. 16 N., R. 3 E.	Sandy loam	7.00	4	2.23	5	5.92
G. W. Conrad	NE. ¼ Sec. 3, T. 17 N., R. 2 E.	Silt loam, sandy loam	37.59	6	3.81	5	4.84
G. L. Campbell	NE. ¼ Sec. 3, T. 17 N., R. 2 E.	Silt loam, sandy loam	16.76	5	3.89	5	6.13
C. N. Mount	NE. ¼ Sec. 3, T. 17 N., R. 2 E.	Clay loam	17.41	6	3.70	5	4.54
Averages					3.31		6.19

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 1.16 feet.

TABLE 21.

Summary of results of alfalfa duty of water investigations, Los Molinos, 1913.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
E. A. Bundy	3¾ miles north of Los Molinos	Silt, clay loam	8.97	4	4.91	5	3.02
E. A. Bundy	3¾ miles north of Los Molinos	Silt loam	4.31	4	6.06	5	7.86
R. W. Ballard	Los Molinos	Silt loam	10.18	4	6.01	5	5.38
G. B. Engle	3 miles north of Los Molinos	Light gravelly clay loam	17.15	5	4.46	5	3.78
G. H. Geer	4 miles north of Los Molinos	Clay loam	9.21	4	7.41	5	7.84
J. F. Hofhenke	11 miles north of Los Molinos	Silt loam	24.59	4	3.78	5	8.10
S. B. Reece	4 miles north of Los Molinos	Clay loam	13.50	4	6.09	5	4.46
John Risse	3¾ miles north of Los Molinos	Silt loam	15.00	4	6.38	5	5.58
A. Wigno	3¾ miles north of Los Molinos	Silt loam	9.13	4	5.08	5	6.29
Averages					5.57		5.81

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 1.16 feet.

TABLE 22.

Summary of results of alfalfa duty of water investigations, Orland, 1913.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
David Brown	N. ½ Sec. 9, T. 22 N., R. 3 W.	Gravelly clay loam	76.45	7	4.73	[1]3	3.98
C. E. Fellerson	NE. ¼ Sec. 24, T. 22 N., R. 3 W.	Coarse gravel impregnated with silt and wash loam	32.45	9	2.83	[2]4	4.44
H. M. Lawton	SW. ¼ Sec. 28, T. 22 N., R. 3 W.	Coarse gravel impregnated with loam	18.61	9	4.29	[2]4	5.29
Roy O'Hair	SE. ¼ Sec. 19, T. 22 N., R. 2 W.	Silt loam	34.20	5	3.16	[2]4	6.40
A. C. Spence	NE. ¼ Sec. 28, T. 22 N., R. 3 W.	Coarse gravel impregnated with silt and wash loam	8.06	10	3.91	[2]4	4.35
Averages					3.78		4.89

[1]Fourth crop destroyed by caterpillars.
[2]Only four crops cut due to shortage of water.
NOTE.—Rainfall November 1, 1912, to October 31, 1913, 0.82 foot.

TABLE 23.

Summary of results of alfalfa duty of water investigations, Woodland, 1913.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
Geo. W. Hughson	NE. ¼ Sec. 6, T. 9 N., R. 2 E.	Silt loam	19.54	3	4.40	5	9.12
H. J. N. Rasmussen	SE. ¼ Sec. 31, T. 10 N., R. 2 E.	Silt loam	15.94	3	4.22	4	5.52
Sylvester Lawson	NE. ¼ Sec. 25, T. 10 N., R. 1 E.	Silt loam	25.63	4	2.38	5	5.91
Wm. Exley	NW. ¼ Sec. 30, T. 10 N., R. 2 E.	Silty clay loam	23.20	4	2.81	4	4.77
R. E. Fisher	NW. ¼ Sec. 30, T. 10 N., R. 2 E.	Silty clay loam	37.71	3	1.30	5	3.46
Frank Hermle	NW. ¼ Sec. 35, T. 10 N., R. 1 E.	Silt loam	23.88	3	3.12	5	6.69
Geo. O. Griffes (south field)	SW. ¼ Sec. 26, T. 10 N., R. 1 E. / SE. ¼ Sec. 27, T. 10 N., R. 1 E.	Fine sandy loam	16.65	4	3.07	5	7.49
Geo. O. Griffes (north field)	SW. ¼ Sec. 26, T. 10 N., R. 1 E.	Silt loam	48.80	3	3.26	3	[1]2.55
D. B. Guile	SW. ¼ Sec. 23, T. 10 N., R. 1 E.	Silty clay loam	28.21	4	2.14	4	4.42
Jackson & Woodard (north plat)	SE. ¼ Sec. 2., T. 10 N., R. 1 E.	Clay loam	10.26	6	3.39	5	7.68
Jackson & Woodard (south plat)	SE. ¼ Sec. 2., T. 10 N., R. 1 E.	Clay loam	9.49	6	3.08	5	8.51
Mrs. Nettie Hadsall	SW. ¼ Sec. 11, T. 10 N., R. 1 E.	Silty clay loam	35.76	2	2.11	4	4.17
Averages					2.94		5.86
Average, excluding young alfalfa							6.16

[1]Young alfalfa.

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 0.61 foot.

Plate XXXIII—A. Impounding Dam, Cache Creek, at Outlet.

B. Capay Diverting Dam, Yolo Water and Power Company.

C. Concrete-lined Canal, Yolo Water and Power Company.

TABLE 24.

Summary of results of alfalfa duty of water investigations, Dixon, 1913.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
J. R. Bloom	SW. ¼ Sec. 24, T. 7 N., R. 1 E.	Clay loam	10.36	6	2.82	3	5.22
Mrs. Letitia Cooper	NW. ¼ Sec. 13, T. 7 N., R. 1 E.	Clay loam	10.01	5	2.27	4	6.92
C. E. Schmeiser	NE. ¼ Sec. 14, T. 7 N., R. 1 E.	Clay loam	36.20	8	3.06	4	5.61
D. W. Wright	SW. ¼ Sec. 12, T. 7 N., R. 1 E.	Clay loam	12.10	8	3.15	4	9.97
M. D. Campbell	SE. ¼ Sec. 11, T. 7 N., R. 1 E.	Clay loam	36.74	12	2.79	3	[1]1.72
E. D. Dudley	NW. ¼ Sec. 12, T. 7 N., R. 1 E.	Silt loam	26.64	15	2.93	5	7.12
Harry McFadyen	SE. ¼ Sec. 2, T. 7 N., R. 1 E.	Clay loam	74.12	15	3.43	5	5.72
Averages					2.92		6.04
Average, excluding young alfalfa							6.76

[1]Young alfalfa.

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 0.61 foot.

TABLE 25.

Summary of results of alfalfa duty of water investigations, Los Molinos, 1914.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
E. A. Bundy	3¾ miles north of Los Molinos	Silt, clay loam	8.97	4	2.34	5	5.78
E. A. Bundy	3¾ miles north of Los Molinos	Silt loam	4.31	4	4.10	5	8.40
O. W. Chambers	7 miles north of Los Molinos	Gravelly clay loam	3.08	6	1.42	6	4.44
G. B. Engle	3 miles north of Los Molinos	Light gravelly clay loam	23.35	6	3.46	5	4.85
G. H. Geer	4 miles north of Los Molinos	Clay loam	9.21	4	6.56	5	6.06
J. F. Hofhenke	11 miles north of Los Molinos	Silt loam	13.27	4	8.46	5	5.75
J. F. Hofhenke	11 miles north of Los Molinos	Silt loam	11.32	4	5.55	5	
S. B. Reece	4 miles north of Los Molinos	Clay loam	13.50	4	5.47	5	5.68
A. Wigno	3¾ miles north of Los Molinos	Silt loam	6.70	4	6.08	5	6.68
H. N. Woodward	4¾ miles north of Los Molinos	Silt, clay loam	9.08	4	3.95	5	8.31
Averages					4.74		6.22

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.74 feet.

TABLE 26.

Summary of results of alfalfa duty of water investigations, Orland, 1914.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
David Brown	N. ½ Sec. 9, T. 22 N., R. 3 W.	Gravelly clay loam	76.45	7	5.04	5	5.49
R. F. Brantley	NW. ¼ Sec. 34, T. 22 N., R. 3 W.	Clay loam	7.75	18	4.03	5	6.13
C. Fellerson	NE. ¼ Sec. 24, T. 22 N., R. 3 W.	Coarse gravel impregnated with silt and wash loam	14.79	8	2.59	5	5.87
H. M. Lawton	SW. ¼ Sec. 28, T. 22 N., R. 3 W.	Coarse gravel impregnated with loam	18.61	13	9.59	5	5.84
E. F. Nickolls	NE. ¼ Sec. 24, T. 22 N., R. 3 W.	Coarse gravel impregnated with silt and wash loam	16.66	9	3.25	[1]4	5.26
J. E. Holland	SW. ¼ Sec. 28, T. 22 N., R. 3 W.	Coarse gravel impregnated with loam	37.00	13	7.56	5	6.26
Roy O'Hair	SE. ¼ Sec. 19, T. 22 N., R. 2 W.	Silt loam	34.20	3	1.04	[1]4	7.17
A. C. Spence	NE. ¼ Sec. 28, T. 22 N., R. 3 W.	Coarse gravel impregnated with silt and wash loam	27.70	10	5.56	Pasture	
Averages					4.83		6.00

[1]Crop pastured after fourth cutting.

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.39 feet.

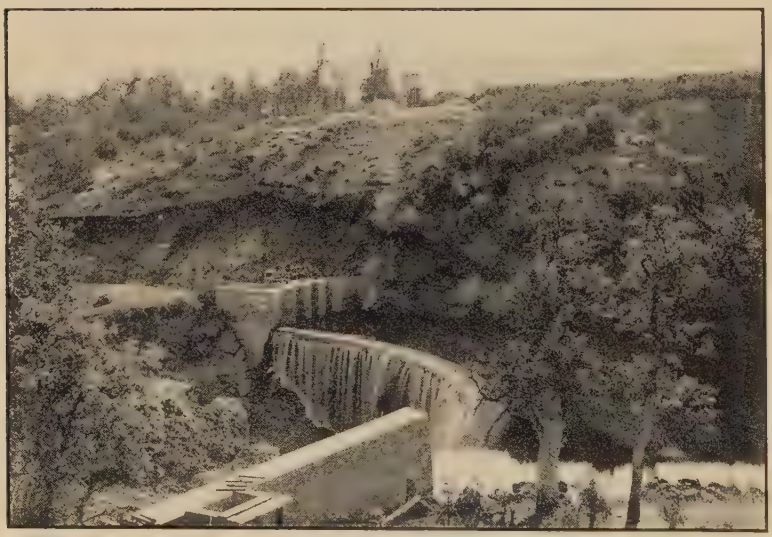
TABLE 27.

Summary of results of alfalfa duty of water investigations, Willows, 1914.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
P. S. Cook	SE. ¼ Sec. 6, T. 20 N., R. 2 W.	Silty clay loam	15.65	9	1.68	[1]3	1.71
C. F. Goos	SW. ¼ Sec. 32, T. 20 N., R. 2 W.	Silty clay loam	13.00	10	1.83	5	5.32
L. E. Tuttle	NW. ¼ Sec. 31, T. 20 N., R. 2 W.	Silty clay loam	35.06	4	1.28	[1]3	3.93
V. E. Breeze	SW. ¼ Sec. 31, T. 20 N., R. 2 W.	Silty clay loam	35.95	6	1.79	[1]3	1.63
Jas. Purdy	SE. ¼ Sec. 31, T 20 N., R. 3 W.	Silty clay	11.37	4	1.69	5	3.75
W. B. Pine	NE. ¼ Sec. 4, T. 20 N., R. 3 W.	Clay adobe	3.34	7	1.97	4	5.39
Averages					1.71		3.62

[1]Crop pastured after third cutting.
NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.39 feet.

Plate XXXIV—A. Checkgate at Siphon Spillway, East Park Reservoir, Orland Project, U. S. Reclamation Service.



B. Diversion Dam, East Park Reservoir, Supply Canal, Orland Project, U. S. Reclamation Service.

TABLE 28.

Summary of results of alfalfa duty of water investigations, Woodland, 1914.

Name	Location	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
Wm. Gould	SE. ¼ Sec. 7, T. 9 N., R. 2 E.	Silty clay loam	19.95	0	0.00	5	4.05
Geo. W. Hughson	NE. ¼ Sec. 6, T. 9 N., R. 2 E.	Silt loam	19.54	2	2.91	5	6.96
H. J. N. Rasmussen	SE. ¼ Sec. 31, T. 10 N., R. 2 E.	Silt loam	10.23	0	0.00	3	3.61
John Beck[1]	NW. ¼ Sec. 30, T. 10 N., R. 2 E.	Silty clay loam	23.20	2	1.58	5	7.28
R. E. Fisher (east plat)	NW. ¼ Sec. 30, T. 10 N., R. 2 E.	Silty clay loam	16.21	0	0.00	3	3.33
R. E. Fisher (west plat)	NW. ¼ Sec. 30, T. 10 N., R. 2 E.	Silty clay loam	21.50	3	2.03	5	4.92
Geo. O. Griffes (south field, east plat)	SW. ¼ Sec. 26, T. 10 N., R. 1 E.	Fine sandy loam	5.48	1	1.41	5	6.12
Geo. O. Griffes (south field, west plat)	SE. ¼ Sec. 27, T. 10 N., R. 1 E.	Fine sandy loam	11.17	1	1.00	5	5.56
Geo. O. Griffes (north field, north plat)	SW. ¼ Sec. 26, T. 10 N., R. 1 E.	Silt loam	24.40	2	1.96	5	7.81
Geo. O. Griffes (north field, south plat)	SW. ¼ Sec. 26, T. 10 N., R. 1 E.	Silt loam	24.40	2	1.96	5	7.40
D. B. Guile	SW. ¼ Sec. 23, T. 10 N., R. 1 E.	Silty clay loam	28.21	2	1.14	4	4.28
Jackson & Woodard (north plat)	SE. ¼ Sec. 2, T. 10 N., R. 1 E.	Clay loam	10.26	3	2.14	5	8.07
Jackson & Woodard (south plat)	SE. ¼ Sec. 2, T. 10 N., R. 1 E.	Clay loam	9.49	3	1.88	5	9.11
Averages for irrigated fields					1.80		6.75
Average for all fields							6.04

[1]The Exley tract in 1913.

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.45 feet.

EXPERIMENTS AT DAVIS.

During the past two years the scope of the irrigation investigations on the irrigation tract at the University Farm at Davis has been materially broadened to include somewhat extensive studies of soil moisture distribution following irrigation. Soil moisture determinations have been made before and after the irrigation of each crop, the depth of soil sampling having varied from 6 to 12 feet. From these results it is possible to show what becomes of the water applied; that is, the depth of penetration, the resulting increase in moisture percentages, and the acre-inches of water taken from the soil per acre in producing the unit weights of the crops grown. As heretofore, the studies at Davis have been under the immediate direction of S. H. Beckett, irrigation engineer in the Office of Experiment Stations and Assistant Professor of Irrigation Practice in the University of California. During the past two years Mr. Beckett has been assisted by O. W. Israelsen, assistant in irrigation, University of California, and Roy Wray.

Alfalfa Investigations.—A summary of the results of these investigations during 1910, 1911, and 1912 was submitted in November, 1912, and printed in the third biennial report of the Department of Engineering. This summary included a diagram showing the respective yields of alfalfa from unirrigated land and from applications of 1, 1.5, 2, 2.5, 3, 4, and 5 acre-feet per acre of irrigation water. Since the continuation of these investigations during 1913 and 1914 has made some changes in the results, the diagram heretofore published has been revised and is submitted herewith, together with a new table giving all of the figures for the five years. It will be noted that, as in the case of the work for 1910, 1911, and 1912, the averages for the 5-year period show but little if any increase in yield on fields that have received in excess of 2.5 acre-feet of irrigation water per acre per season. While in the years of more than normal rainfall the seasonal yields have increased on all of the fields, in no case has it been found economical to apply more than 2.5 acre-feet per acre per year. The cost data assembled in the table indicate that in some cases the larger yields have resulted in a net loss. A 3-year record has been obtained on a small plat to which water has been applied at the rate of 5 acre-feet of water per acre per year. Both the diagram and table show that the use of so much water has been of no avail, and inspection of the field indicates that the crop is being rapidly drowned out and supplanted by a rank water grass.

A full discussion of the results of the alfalfa studies at Davis will be withheld to accompany the discussion heretofore referred to of the results on the farms elsewhere in Sacramento Valley. It can be stated at this time, however, that results to date indicate that it is uneconomical to the individual farms to apply more than 2.5 acre-feet of water per acre per annum on the sandy loams of the Sacramento Valley where the crop grown is alfalfa; and, without undertaking at this time to make definite comparison between the results at Davis and results on the other farms under observation, it can be stated that, on the average, the figures obtained away from Davis substantiate those obtained at Davis.

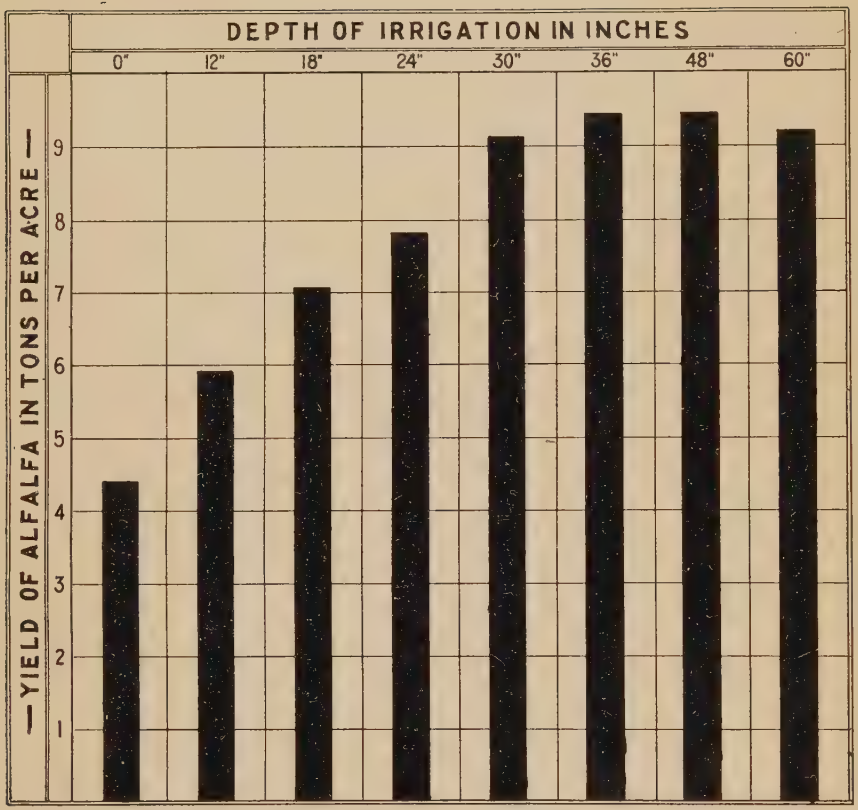
The period covered by the alfalfa studies at Davis shows a variation in winter precipitation from a minimum of 8.85 inches in 1912–13 to a maximum of 27.8 inches in 1913-14, averaging for the five years 16.36 inches.

TABLE 29.

Summary of results of investigations of duty of water for alfalfa at Davis for 1910, 1911, 1912, 1913, 1914.

Depth water applied, inches	Yield in tons per acre						Value of hay					
	1910	1911	1912	1913	1914	Average	1910	1911	1912	1913	1914	Average
0	3.85	6.02	5.52	2.75	3.94	4.42	$26 95	$42 15	$49 68	$27 50	$15 76	$32 41
12	4.75	7.52	6.51	4.31	6.40	5.90	33 25	52 64	68 59	43 10	25 60	42 63
18	-------	-------	7.02	5.69	8.42	7.04	-------	-------	63 18	56 90	33 68	51 29
24	6.00	8.38	8.32	6.37	9.96	7.81	42 00	58 65	74 88	63 70	39 84	55 81
30	7.53	9.61	9.43	7.97	11.06	9.12	52 70	67 25	84 87	79 70	44 24	65 75
36	7.58	9.33	9.38	8.22	12.48	9.40	53 05	65 30	84 42	82 20	49 92	66 98
48	8.45	9.64	8.87	8.97	11.20	9.43	59 15	67 50	79 83	89 70	44 80	68 20
60	-------	-------	10.04	7.03	10.51	9.19	-------	-------	90 36	70 30	42 04	67 57

Value of hay in stack $7.00 per ton in 1910 and 1911, $9.00 in 1912, $10.00 in 1913, and $4.00 in 1914.



DUTY OF WATER ON ALFALFA~EXPERIMENTAL PLAT
DAVIS CAL.~1910·11·12·13 AND 1914

Plate XXXV.

TABLE 29—Continued.

Depth water applied, inches	Cost of production						Net profit per acre					
	1910	1911	1912	1913	1914	Average	1910	1911	1912	1913	1914	Average
0	$8 65	$13 50	$12 40	$6 19	$8 86	$9 92	$18 30	$28 65	$37 28	$19 31	$6 90	$22 09
12	13 40	19 60	17 35	12 40	17 10	15 97	19 85	33 04	41 24	30 70	8 50	26 67
18	-------	-------	19 85	16 85	23 00	19 90	-------	-------	43 33	40 05	10 68	31 35
24	18 90	24 20	24 10	19 73	27 80	22 95	23 10	34 45	50 78	43 97	12 04	32 87
30	23 15	27 85	27 35	24 18	31 15	26 73	29 55	39 40	57 52	55 52	13 09	39 02
36	24 15	28 05	28 10	25 60	35 20	28 22	28 90	37 25	56 32	56 60	14 52	38 72
48	27 80	30 25	28 80	29 00	34 00	29 97	31 35	37 25	51 03	60 70	10 80	38 23
60	-------	-------	33 65	26 33	34 13	31 37	-------	-------	56 71	43 97	7 91	33 20

NOTES.—Labor of production figured at $2.25 per ton. Water figured at $1.70 per acre-foot. Labor for irrigation figured at 50 cents per acre per irrigation.
Seasonal rainfall: 1909-10, 11.90 inches; 1910-11, 23.80 inches; 1911-12, 9.46 inches; 1912-13, 8.85 inches; 1913-14, 27.80 inches.

Grain Investigations.—In the fall of 1911 a portion of the experimental area at Davis then seeded to alfalfa was turned under and a rotation of field crops started. It was not intended to make a study of the proper rotation of field crops, but rather to study the duty of water under rotation practice. Including two seasons before the experiments under rotation were started, barley investigations have now extended over five seasons, while studies of duty of water on wheat have been in progress since 1912. The results to date are assembled in the two tables given below. The yields in hay and grain, values, irrigation cost, and depths of water applied are the averages for the entire period.

TABLE 30.

Summary of results of duty of water investigations with barley at Davis, 1910-1914; average rainfall, 16.36 inches.

Number of irrigations	Depth of water applied, inches	Yields in pounds per acre		Total value grain at $1.25 per 100 pounds	Average cost of irrigation per acre at 25 cents per acre-inch
		Hay	Grain		
0	-------	2,426	940	$11 75	-------
1	5.70	4,272	1,593	19 92	$1 45
2	11.10	5,380	2,170	27 12	2 75

TABLE 31.

Summary of results of duty of water investigations with wheat at Davis, 1912-1914; average rainfall, 15.76 inches.

Number of irrigations	Depth of water applied, inches	Yields in pounds per acre		Total value grain at $1.50 per 100 pounds	Average cost of irrigation per acre at 25 cents per acre-inch
		Hay	Grain		
0	-------	2,703	637	$9 55	-------
1	6.0	4,267	1,157	17 35	$1 50
2	10.1	6,100	1,529	22 94	2 52
2[1]	15.5	5,050	1,029	15 45	3 88

[1]Average of 1913–1914 only.

The average rainfall for the periods covered by the above tables is slightly below the normal of 17.8 inches, yet the results in general show a profitable increase in yields with the increased amounts of water applied up to at least 10 acre-inches of water per acre in two irrigations. As might be expected, the results for the individual seasons show the greatest increases in yields due to irrigation in the seasons of least rainfall. The crop harvested in 1914, which received a seasonal rainfall of 27.08 inches, indicates a definite loss due to irrigation, the wheat crop especially showing a decided decrease in yield with the increase in the amount of water applied. In the spring irrigation of grain crops no set schedule was followed, but in each case the time of irrigation was made to fit the needs of the crop.

In addition to the grain experiments mentioned above, a small experiment was made in the fall of 1912 and the fall of 1913 in irrigating grain land before seeding, but with no further irrigation given. In 1913 a yield at the rate of 3,306 pounds of barley per acre was obtained from a plat that had received a 12-inch irrigation prior to seeding in the fall of 1912 and then a rainfall of 8.85 inches. Adjacent land which had not received the 12-inch fall irrigation produced at the rate of only 448 pounds per acre. In 1914 land which had received a 10-inch fall irrigation prior to seeding and then a rainfall of 27.8 inches yielded at the rate of 2,000 pounds of grain per acre as against 1,790 pounds per acre from the plat that had received no fall irrigation. It is proposed to continue this work over a longer period before attempting to draw final conclusions. It is evident, however, that where feasible a fall irrigation prior to seeding will prove to be very beneficial if the winter rainfall turns out to be light.

Indian Corn.—The studies of duty of water for Indian corn were started in 1910. Irrigation water has been applied in accordance with the needs of the crop. Owing to unfavorable conditions the 1912 crop was a failure but the results for 1910, 1911, 1913, and 1914 are given in the following table:

TABLE 32.

Summary of results of duty of water investigations with Indian corn at Davis, 1910, 1911, 1913, and 1914; average seasonal rainfall 18.16 inches.

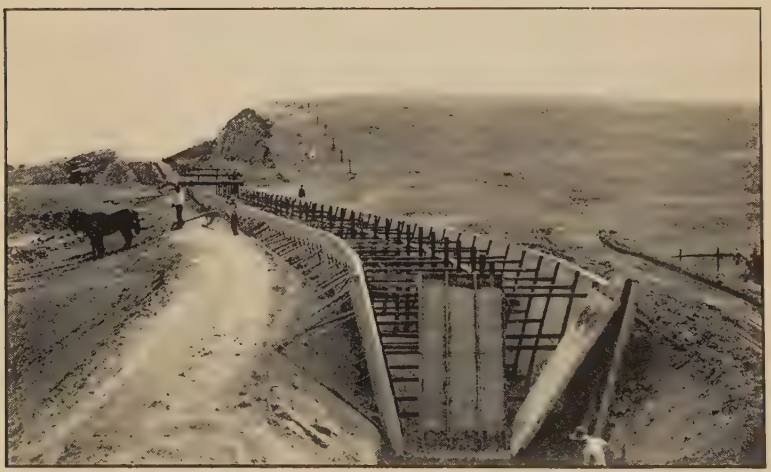
Number of irrigations	Depth of water applied, inches	Yields of green silage, tons per acre	Total value at $2.50 per ton	Total cost of irrigation
0		4.00	$10 00	
1	3.3	6.22	15 55	$1 62
2	6.0	7.48	18 70	2 75
3	9.0	8.52	21 30	4 12
4	14.0	8.42	21 05	5 90

Owing to the differences in seasonal rainfall, the figures indicate that a wide variation in seasonal yields was obtained with the application of equal amounts of water. In each season, however, and irrespective of rainfall, substantial increases in the yields have resulted from the irrigation water applied. The table indicates that, on the average, the most economical yields have been obtained by giving three irrigations averaging three acre-inches per acre each.

Other Crops.—Some attention has been given to the studies of irrigation of sugar beets and potatoes. The yields of sugar beets during the first seasons of observations were gratifying, a yield of 18.6 tons of beets per acre having been obtained from the use of 17.8 acre-inches of water per acre applied in three irrigations, as against only 4.85 tons per acre from the fields that received no irrigation water. During 1913 and 1914 the beet crops were almost totally destroyed by blight.

During the seasons of 1912, 1913, and 1914 a small demonstration has been made of the feasibility of following grain crops with a summer irrigated crop. The summer crops used have been corn and maize cut for green summer feed or ensilage. The

Plate XXXVI—A. Concrete-lined Canal, South San Joaquin Irrigation District.



B. Concrete Canal Lining Before Bracing and Backfilling Done, South San Joaquin Irrigation District.

maximum results show yields of 2,556 pounds of grain and of 15.4 tons of green corn ensilage per acre from the same land in one season. If means permit, further experiments along this line will be made.

STUDIES OF IRRIGATION OF GRAIN ABOUT WOODLAND.

1913–1914.

Although grain is not usually irrigated in Sacramento Valley, there was a total of 2,419 acres of barley, oats, and wheat watered in 1913 in the territory immediately adjacent to Woodland, due to the deficiency in the rainfall of the preceding winter. Of this, 1,884 acres were in barley, 500 acres in oats, and 35 acres in wheat. One thousand seven hundred and thirty-nine acres of barley and 300 acres of oats were watered from the Moore and lower Adams ditches of the Yolo Water and Power Company, and the remainder from pumping plants. It was possible, in connection with the alfalfa duty of water investigations, to gather data about this grain irrigation in 1913 and in many instances to supplement the data gathered in 1913 with crop yields on the same fields in 1914 without irrigation. The results are given below in some detail, and should have interest to all grain growers in Sacramento Valley. The data were gathered and analyzed by Wells A. Hutchins, field assistant.

As most of the grain land that was irrigated had not been especially prepared for irrigation there were large higher-lying areas in many fields that could not be reached by the water. In some cases straight parallel furrows were dug from field ditches, and in others the water was turned loose directly from the ditches and guided about the land. Albert Hannum's tract was very carefully prepared with a system of long furrows following the main ridges and short parallel furrows deviating from them, usually at right angles, with the result that only a small area remained unwatered. The cost of preparation of this field, including surveying, furrowing, and subsequent plowing in of the furrows, was $1.10 per acre.

The figures on applications and cost of water were computed in most cases from the measurements of the Yolo Water and Power Company. The depths of water applied to barley ranged from .24 foot to 2.85 feet, with an average of .98 foot; to oats 1.19 to 1.90 feet, averaging 1.62 feet; and to wheat 1.03 feet; with an average depth applied to all grain of 1.11 feet. The cost of water for barley varied from $0.36 to $4.28 per acre, averaging $1.48; for oats $2.85, and for wheat $1.54; with a general average of $1.76 per acre.

The yields from most of the irrigated barley fields, ascertained usually from the growers, ranged from 10 to 37 sacks per acre, averaging 23 sacks; of oats 1.5 to 2.5 tons of hay, averaging 2.2 tons; and of wheat 1.3 tons per acre. The few figures gathered on unirrigated barley showed a range of from practically nothing to 13 sacks per acre, with an average of probably 8 sacks per acre. Thus with an expenditure of only $1.76 per acre for water and probably an equal amount for labor and preparation for irrigation, the yields of grain in this dry year were more than doubled.

Owing to heavy rainfall in the winter of 1913–1914 there was only one grainfield irrigated in this section in 1914, that of L. P. Jones, who applied .58 acre-foot per acre on 12 acres of barley about June 1, at a cost for water of $0.88 per acre, with a resulting yield of 12 sacks per acre, the low yield being attributable to lateness of seeding and to lack of thoroughness of preparation. The yields in 1914 from 1,424 acres of the area irrigated in 1913 ranged from 9 to 40 sacks of barley per acre, with an average of 22 sacks per acre.

The normal precipitation at Davis during the period November to May, inclusive, is 15.96 inches. During that period in 1913 the rainfall was 7.20 inches, and in the corresponding period in 1914, 28.04 inches. Thus with 7.20 inches of rainfall in 1913 unirrigated grainfields yielded only about 8 sacks to the acre, while with a total of 20.52 inches of combined rainfall and irrigation water, and with a relatively small additional expenditure, the yield was more than doubled and was made to equal the yield in 1914, a season of abundant precipitation and normal growing conditions.

TABLE 33.

Summary of results of grain irrigation near Woodland, 1913–14.

Crop and name	Acres irrigated	Date of irrigation, 1913	Total depth applied, 1913, feet	Cost of water per acre, 1913	Yield per acre, 1913, irrigated		Yield per acre, 1914, unirrigated	
					Grain, sacks	Hay, tons	Grain, sacks	Hay, tons
Barley:								
Geo. Hoppin	100	Feb. 24 Apr. 16	0.48 1.46	$0 72 2 19	20	..	28	.....
John Clark	18	Mar. 13	0.38	0.50	24	....	[1]__	.....
John Clark	80	May	1.54	2 30	25	....	19	.....
Roy Woodard	80	Apr. 19	1.25	1 87	15	....	20	.....
Roy Woodard	12	----------	[2]0.98	----------	32	....	25	.....
Wm. Rieff	30	Apr. 28	0.83	1 25	20	.....	.....	.....
C. F. Duncan	8	Mar. 14	0.31	0.47	.....	2.5	.....	.....
Floyd Beebe	10	Apr. 13	1.07	1 60	.....	.....	.....	.....
H. B. Hurd	5	Apr. 16	0.93	1 40	.....	.....	.....	.....
J. C. Kaupke	12	Apr. 10	0.88	1.31	23	.....	40	.....
E. A. Bullard	60	Apr. 11	1.67	2 50	25		[3]10 [4]16	.....
Dan Farnham	20	Apr. 14	1.40	2 10	.....	[5]4.0	[5]14	.....
F. C. Worley	40	Apr. 16	0.85	1 28	.....	.....	.....	.....
Marvin Howard	10	Apr. 18	0.60	0 90	.....	.....	.....	.....
Dean Beeman	29	Apr. 19	1.24	1 86	27	.....	[1]__	.....
Dean Beeman	7	Apr. 22	0.67	1 00	23	.....	.....	2.5
Wm. Eakle	45	Apr. 19	0.61	0 91	10	.....	[6]__	.....
W. H. Browning	30	Apr. 19	1.56	2 34	21	.....	21	.....
Mrs. Chas. Elston	20	Apr. 21	2.45	3 68	.....	.....	.....	.....
Mrs. Chas. Elston	17	May 3	1.47	2 21	.....	.....	.....	.....
Peter McLaughlin	20	Apr. 21	0.93	1 40	.....	.....	.....	.....
Martin & Suggett	75	Apr. 22	0.91	1 36	24	.....	30	.....
Martin & Suggett	16	Apr. 7 Apr. 28	0.75 1.22	1 12 1 83	24	.....	18	.....
Clarence F. Day	80	Apr. 24	0.67	1 00	10	.....	9	.....
Baird Bros.	20	Apr. 25	1.05	1 58	.....	.....	.....	.....
Louis Ulrich	38	Mar. 6	0.65	0 97	33	.....	31	.....
Louis Ulrich	38	Mar. 7 May 6	0.77 0.63	1 16 0 95	28	.....	28	.....
Louis Ulrich	12	----------	[2]0.98	[2]1.47	24	.....	.....	.....
Wm. M. Browning	10	May 1	0.87	1 30	19	.....	[1]__	.....
Wm. M. Browning	3	May 6	1.11	1 67	18	.....	[1]__	.....
Rumsey Bros.	40	Mar. 9 Apr. 23	0.80 0.67	1 20 1 00	25	.....	[7]31	.....
Rumsey Bros.	5	----------	[2]0.98	[2]1 47	.....	1.0	31	.....
Dick Snavely	5	Mar. 10	0.93	1 40	.....	.....	.....	.....
T. J. Vaughn	30	Mar. 14	2.85	4 28	37	.....	30	.....
Dick Brown	140	Mar. 10	0.69	1 03	28	.....	16	.....
T. B. Gibson	250	Mar. 13	0.71	1 07	33	.....	.....	.....
P. N. Ashley	20	Mar. 21	0.90	1 35	.....	.....	.....	.....
Garrett Van Zee	5	Mar. 22 Apr. 28	0.74 0.30	1 11 0 45	.....	.....	.....	.....
Sieferman Bros.	100	Apr. 2	0.69	1 04	15	.....	.....	.....
Fitch Bros.	30	May 4	0.93	1 40	.....	.....	.....	.....
H. J. N. Rasmussen	15	Mar. 11	1.64	2 46	32	.....	.....	.....
T. Fishback	38	Mar. 11	0.24	0 36	21	.....	30	.....
Fred Ulrich	100	Apr. 29	1.09	1 64	17	.....	17	.....
Albert Hannum	145	Mar. 15	0.99	1 85	21	.....	12	.....
D. N. Brown	16	Apr. 14	0.71	1 06	21	.....	[8]30	.....
Oats:								
Alameda Sugar Beet Co.	300	Apr. 12	1.90	2 85	.....	2.5	[9]30	.....
Alameda Sugar Beet Co.	200	----------	1.19	----------	.....	1.5	.....	.....
Wheat:								
Louis Ulrich	35	Apr. 16	1.03	1 54	.....	1.3	[1]__	.....
Total	2,419	----------	----------	----------	.....	.....	.....	.....
Average	.....	----------	1.11	$1 76	23	2.1	22	2.5

[1]In alfalfa. [2]Estimated. [3]50 acres wheat. [4]10 acres barley. [5]Mostly wild oats [6]In pasture. [7]19 acres. [8]5.5 acres. [9]Barley.

STUDIES OF RICE IRRIGATION IN SACRAMENTO VALLEY.

During the past three or four years, and largely through the leadership of the Bureau of Plant Industry of the Department of Agriculture, rice has been added to the important California agricultural products. Many inquiries have been received by us regarding the proper irrigation of this crop and to put us in possession of information needed to answer these inquiries, studies have been made of rice irrigation in Sacramento Valley in conjunction with work there on the duty of water for alfalfa. During 1912 and 1913 the work of the Office of Experiment Stations in this connection was confined to measurements of the amount of water applied to rice fields and studies of the preparation of land for rice irrigation and of the application of water to the crop. Beginning with 1914 an agreement was entered into between the Office of Experiment Stations and the Bureau of Plant Industry under which cooperative experiments are being conducted on and adjacent to the rice experiment station of the Bureau of Plant Industry near Biggs. It is too early to publish the results of the studies on the rice experiment tract at Biggs, but an outline of what is being done there, together with such information as has been gathered by our agents from the rice growers of Sacramento Valley, and also a statement of the general conditions under which rice is being irrigated, is given below. Such work as the Office of Experiment Stations has done in this connection has mainly been carried on by Ralph D. Robertson, irrigation engineer, and the data given below are from a report of work done and of observations made by him.

The first planting of rice and the first experimental work in growing rice in Sacramento Valley were started in 1909 by the Bureau of Plant Industry, United States Department of Agriculture. Experimental work was carried on in 1910 and 1911 and the production of rice on a commercial basis was started in 1912, when there were approximately 1,200 acres planted. In 1913 the area given over to rice culture was 6,000 acres and in 1914 approximately 15,000 acres, the latter distributed as follows: Butte County, 11,000 acres; Colusa County, 3,100 acres; Yuba County, 600 acres; Glenn County, 150 acres; Sacramento County, 100 acres; Yolo County, 70 acres.

The most essential requirement in the growing of rice aside from suitable soil and climate is the assurance of an abundant and unfailing water supply, especially in the late summer months when the crop is maturing. Soon after planting rice develops into an aquatic plant and requires water throughout the growing season. The irrigation season is divided into two periods, according to the growth of the plant and the amount of water applied. Under present practice in the first period water is applied four to six times to sprout the seed and to keep the soil thoroughly moist, without having water standing on the field. There may be seasons when there is sufficient moisture in the soil to germinate the seed without irrigating, but as a rule the practice is to apply water every seven to ten days, to keep the soil from drying out. Rice growers in Butte County state that probably the most critical operations in the irrigation of rice are the first and second waterings. It is essential that when these are given the fields shall be rapidly drained. According to the growers this is due to the danger of rotting the seed if the water is allowed to remain on the field.

When the rice is from four to six inches high, which is usually from four to six weeks after the time of planting, water is turned on and the fields are kept submerged until the grain is in the milk and well formed, which is from ninety to one hundred twenty days after initial submergence. A small flow of water is run into the checks continually and a common practice is occasionally to drain off a small amount of the water, the idea in this being to keep fresh water on the rice. This tends to prevent stagnation and also serves to replenish the water lost through evaporation, which is sometimes as much as one-half inch per twenty-four hours. The depth to which the fields are kept flooded is from 3 to 5 inches, and in some cases as high as 8 inches.

As already indicated the largest area devoted to rice in Sacramento Valley is in Butte County, in the vicinity of Gridley, Biggs, and Richvale. Water is delivered to the rice fields in this territory by Sutter-Butte Canal Company, the supply being taken from Feather River about 10 miles above Gridley. A large branch lateral diverts from the main canal northeast of Biggs and carries water in a northeasterly direction to the vicinity of Richvale, from whence it is distributed in numerous laterals. A pumping station has been established by the Richvale Land Company about .75 mile west of Richvale, where water is pumped out of Sutter-Butte Canal and thence distributed by gravity.

To secure water for rice under Sutter-Butte Canal it is necessary to locate a water-right on the piece of land it is desired to irrigate, which becomes appurtenant to the land. The initial cost is $10 per acre, and the annual rental charge for rice is then $5 per acre. The water-right contract calls for a continuous flow of one cubic foot per second for each 53.33 acres, or three times the amount stipulated for alfalfa. No attempt has been made to measure water to irrigators, but the general practice has been to allow all the irrigators could use. This has resulted in an extravagant use of water.

As already stated, independent measurements were made by the Office of Experiment Stations in 1912 and 1913 to determine the use of water on rice fields in Sacramento Valley. In 1912 the net duty of water obtained on one 50-acre field near Biggs was 5 acre-feet per acre. Measurements in 1913 on a few fields near Gridley, where much water was wasted, showed the total amount used for the season to be 7.5 acre-feet per acre.

The cooperative rice irrigation experiments begun in 1914 in conjunction with the Bureau of Plant Industry were made on a field of 39.48 acres in section 35, T. 19 N., R. 2 E. The total amount of water used in 1914 in maturing the crop was 4.65 acre-feet per acre. This probably represents the minimum use of water on rice in the territory served by Sutter-Butte Canal. It is realized that results for a single year can not be accepted as final and it is hoped the studies can be continued.

The field on which the above measurements were made was planted April 15th and first irrigated April 30th. Previous to June 12th, when the field was submerged, there were six irrigations and the total depth of water applied up to June 12th was 1.04 acre-feet per acre. During these six irrigations an average head of 6 to 12 cubic feet per second was used in flooding the field. A good moisture content was maintained in the soil, but no water was allowed to remain on the field. From June 12th to October 11th a uniform depth of about 4 inches was constantly maintained on the field. The average flow during this 121-day period of submergence varied from .50 to .75 cubic foot per second. Occasionally a small amount of water would be removed from the field, but the stream in each case was too small to be measured and the 3.61 acre-feet per acre which was applied during the flooded period of growth may be taken as the net amount used during this time. Measurements of the water applied were made by means of a 2-foot Cipolletti weir installed at the entrance to the field where readings were taken daily. The field is divided into 7 contour checks, the largest of which comprises 11 acres. The difference of elevation between the checks is 3 inches. Water is admitted into the higher check and from there in turn passes into lower checks through boxes placed in the levees. The interior levees were made with a ridger and have a base of 3.5 feet and are 12 inches in height. No levelling was required on the field and the cost of making levees was less than $1 per acre. The cost of plowing, harrowing and dragging in preparing the seed bed was $4 per acre. The soil is black adobe underlain with hardpan and is typical of the area devoted to rice culture in the vicinity of Biggs and Richvale.

With the data now at hand it is estimated that a duty of 5 to 6 acre-feet per acre is sufficient to mature a crop of rice in Sacramento Valley, at least with more careful use of water and better preparation of land. In Louisiana and

Arkansas the amount of water pumped for rice is from 1.25 to 2 acre-feet per season. To this, however, should be added the rainfall, which may be from 10 to 20 inches during the growing period. The rainfall during the growing season in Sacramento Valley is practically negligible and, moreover, the humidity of the atmosphere is also much less than in the southern states, thereby necessitating a greater use of water here.

When sufficient water can be obtained by low lifts from wells or from river channels, it is feasible to pump water for rice. With the prevailing prices of either distillate or electric power in Sacramento Valley, the cost of pumping will be in the neighborhood of 4 to 5 cents per acre-foot of water lifted one foot high. If the water is lifted 20 feet the cost will thus be from 80 cents to $1 per acre-foot, or $4 to $5 per acre irrigated if 5 acre-feet are applied. Pumping water for rice is widely resorted to in the southern states, but owing to different conditions it is difficult to make a comparison of costs with those that might obtain in California. In Louisiana and Arkansas steam plants are used, in which wood, coal, or oil is used for fuel. The Office of Experiment Stations has made investigations covering the cost of pumping water for rice in the southern states.* The average cost of pumping at well plants tested in Louisiana was $6.67 per acre irrigated, with an average lift of 20 feet, while in Arkansas the average cost was $11.61 per acre, with a lift of approximately 40 feet. These costs are based on the pumping of 1.25 acre-feet per acre.

One very important factor in the irrigation of rice is to have the land well prepared to receive water. The fields in Butte County are prepared by the contour method, the checks ranging in size from 2 to 12 acres, and averaging about 5 acres. The size of the checks will naturally depend upon the fall and topography of the land, but as a rule a difference of elevation of 3 to 5 inches between checks will be found satisfactory. The outside levees should have a base of at least 6 feet, a width on top of 2 feet, and be from 2 to 2.5 feet high. The most satisfactory levees are made with a Fresno scraper, although the interior levees can often be made more cheaply with a "crowder" or "pusher." There are various forms of land levelers on the market that do satisfactory work. The cost of preparing land varies largely with the individual field. There are numerous fields around Gridley and Biggs where levees have been made at a cost of $1 per acre and no levelling was required. On other fields the cost of preparing land has been about $10 per acre. The cost probably should not exceed $15 per acre in other sections where rice may be grown.

IRRIGATION PUMPING PLANTS IN CALIFORNIA.

According to the irrigation census taken in 1910 under cooperative agreement between the Bureau of the Census and this office, 9,297 irrigation pumping plants were in operation in California in that year. Since then there has been a large increase in that number, especially during the dry season of 1912 and 1913. In order to ascertain approximately what that increase has been, letters were addressed to the principal manufacturers, or their state representatives, whose irrigation pumping plants have been installed in California, care being taken to avoid duplications. Replies were received from all but three of the dealers addressed, although a few of the replies received were stated to be merely conservative estimates. It is realized that some of the installations reported replaced old plants. On the other hand, some of the smaller dealers who handle irrigation pumping plants in California have undoubtedly not been included. Counting that the replacements and the omissions about equal each other, and further counting 1,500 plants as having been installed by the larger dealers who did not respond, at the close of the season

*U. S. Department of Agriculture, Office of Experiment Stations Bulletin No. 201.

of 1914 the figures for the entire state stood approximately as given in the table below:

TABLE 34.

Estimate of Irrigation Pumping Plants Installed in California Since January 1, 1911, With Number Reported in Irrigation Census of 1910.

Number reported in irrigation census of 1910	9,297
Sacramento Valley	432
San Joaquin Valley	844
Santa Clara Valley	227
Salinas Valley	63
Northern and central California, unsegregated	4,076
Los Angeles County	2,527
Ventura County	120
Santa Barbara County	30
Orange County	287
San Bernardino County	199
San Diego County	365
Riverside County	325
Imperial County	61
Southern California, unsegregated	6
All California, unsegregated	4,230
Estimate for larger dealers not reporting	1,500
Total	24,589

Irrigation Pumping Plants in Woodland Area.—While studying the duty of water for alfalfa in the Woodland section during 1913 and 1914, Mr. Wells A. Hutchins, field assistant, took a complete census of the irrigation pumping plants now operating within the area. While the data are somewhat detached, a tabular summary of them is included herewith because it is believed that the data will have value both as showing the extent and character of this form of irrigation development in an important portion of Sacramento Valley, and as furnishing information of local value to the people about Woodland. It will be noted that in spite of the general improvements in the Cache Creek irrigation system recently brought about by the Yolo Water and Power Company, a total of 74 pumping plants, indicating that pumping and gravity irrigation systems develop together, have been installed there since January 1, 1911. Many plants that were installed prior to January 1, 1911, are no longer in use, either having been worn out or superseded by the gravity system.

TABLE 35.

Summary of irrigation pumping plants in Woodland area.

Owner	Year of installation	Power	Pump	Connection	Crop being irrigated	Notes
Verney Kramer	1898	35 h.p. gas engine	8 in. centrifugal		Alfalfa and fruit	3 wells.
City of Woodland	1902	50 h.p. motor	8 in. centrifugal	Direct	Lawns	Includes domestic use.
Lawrence Kramer	1906	50 h.p. gas engine	10 in. centrifugal		Alfalfa and fruit	3 wells in bed of Cache Creek.
T. G. Baty	1909	25 h.p. gas engine	6 in. centrifugal	Belt	Alfalfa and almonds	2 wells in bed of Cache Creek.
M. R. Dozier	1911	15 h.p. motor	7 in. centrifugal	Direct	Fruit and alfalfa	Pumps from Cache Creek.
J. W. Gallup	1911	10 h.p. motor	6 in. centrifugal	Direct	Fruit and alfalfa	Pumps from Cache Creek.
Alameda Sugar Beet Company	1911	100 h.p. motor	12 in. centrifugal	Belt	Sugar beets	Not operating in 1914.
A. W. Morris & Sons	1911	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa, corn, grain, rice.	
Alameda Sugar Beet Company	1911	75 h.p. motor	12 in. centrifugal	Belt	Sugar beets	Not operating in 1914.
H. E. Coil	1911	20 h.p. motor	8 in. centrifugal	Direct	Alfalfa.	
C. Q. Nelson	1911	25 h.p. motor	8 in. centrifugal	Direct	Vines and alfalfa	Pumps from Cache Creek.
Fowler & Grady	1912	25 h.p. gas engine	5 in. centrifugal	Belt	Alfalfa, fruit and vegetables.	Pumps from Cache Creek.
J. D. Stevens	1912	3 h.p. motor	3 in. centrifugal	Belt	Vegetables.	
Harold Armstrong	1912	20 h.p. motor	8 in. centrifugal	Direct	Alfalfa.	
Jackson & Woodard	1912	25 h.p. motor	8 in. centrifugal	Direct	Alfalfa	2 wells.
J. W. Gallup	1912	15 h.p. motor	6 in. centrifugal	Direct	Fruit.	
Sacramento Valley Sugar Company	1912	150 h.p. motor	15 in. centrifugal	Direct	Sugar beets	12 wells. Not operating in 1914.
Harry Daniels	1912	25 h.p. gas engine	8 in. centrifugal	Belt	Fruit and vines	Pumps from Cache Creek.
Sacramento Valley Sugar Company	1912	100 h.p. motor	12 in. centrifugal	Belt	Sugar beets and grain	7 wells. Not operating in 1914.
Sacramento Valley Sugar Company	1912	100 h.p. motor	12 in. centrifugal	Direct	Sugar beets	4 wells. Not operating in 1914.
Sacramento Valley Sugar Company	1912	75 h.p. motor	12 in. centrifugal	Belt	Sugar beets	3 wells. Not operating in 1914.
W. E. Proctor	1912	7½ h.p. motor	3 in. centrifugal	Belt	Alfalfa, fruit and vegetables.	Pumps from Cache Creek or well.
Chas. Laugenour	1912	50 h.p. motor	10 in. centrifugal	Belt	Alfalfa.	
Alameda Sugar Beet Company	1912	25 h.p. motors, 4	4 mult. stage cent.	2 direct, 2 belt.	Sugar beets and alfalfa	2 operating in 1914.
Wm. Zimmerman	1912	35 h.p. motor	8 in. centrifugal	Belt	Alfalfa.	
H. E. Coil	1912	35 h.p. motor	10 in. centrifugal	Direct	Alfalfa.	
City of Woodland	1912	50 h.p. motor	8 in. centrifugal	Direct	Lawns	Includes domestic use.
Warner, Stidger & Kennah	1912	35 h.p. motor	8 in. centrifugal	Belt	Alfalfa	Pumps from Willow Slough.
O. M. Colburn	1912	20 h.p. motor	7 in. centrifugal	Belt	Alfalfa	Pumps from Willow Slough.
Sacramento Valley Sugar Company	1912	100 h.p. motor	12 in. centrifugal	Direct	Sugar beets	6 wells. Not operating in 1914.
H. Germeshausen	1912	7½ h.p. motor	4 in. centrifugal	Belt	Alfalfa.	
G. H. Hecke	1912	5 h.p. motor 10 h.p. motor	3 in. centrifugal	Belt	Trees	Includes domestic use.

TABLE 35—Continued.

Owner	Year of installation	Power	Pump	Connection	Crop being irrigated	Notes
Morris & Lewis	1912	50 h.p. motor	10 in. centrifugal	Belt	Alfalfa and vegetables.	
A. Y. Dick	1913	75 h.p. motor	10 in. centrifugal	Belt	Alfalfa	3 wells.
W. B. Jennings	1913	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa.	
Woodland Cemetery	1913	7½ h.p. motor	2 in. centrifugal	Direct	Lawn.	
Jos. Kerr	1913	7½ h.p. motor		Belt	Alfalfa and vegetables.	
J. W. Considine	1913	15 h.p. motor	6 in. centrifugal	Direct	Alfalfa.	
D. E. McGriff	1913	75 h.p. motor	12 in. centrifugal		Sugar beets and alfalfa.	
Wirt Nelson Est.	1913	30 h.p. motor			Vines.	
S. and H. Hiddleson	1913	35 h.p. motor	8 in. centrifugal	Belt	Alfalfa	Pumps from Willow Slough.
A. D. Sifford	1913	20 h.p. motor	6 in. centrifugal	Belt	Alfalfa	Pumps from Willow Slough.
Alameda Sugar Beet Company	1913	150 h.p. motor	12 in.mult.st.cent.	Belt	Sugar beets	Not operating in 1914.
J. E. Scarlett	1913	50 h.p. motor	10 in. centrifugal	Belt	Alfalfa and fruit.	
J. P. Raiche	1913	7½ h.p. motor	4 in. centrifugal		Alfalfa and vegetables.	
Richard Fisher	1913	10 h.p. motor	4 in. centrifugal	Direct	Alfalfa.	
G. P. Hatcher	1913	30 h.p. motor	8 in. centrifugal	Belt	Alfalfa.	
R. L. Harter	1913	20 h.p. motor	8 in. centrifugal	Direct	Alfalfa.	
W. C. Hadley	1913	20 h.p. motor	8 in. centrifugal	Belt	Alfalfa.	
Hayden Bros.	1913	30 h.p. motor	8 in. centrifugal	Direct	Alfalfa and fruit.	
R. E. Fisher	1913	25 h.p. gas engine	8 in. centrifugal	Belt	Alfalfa	3 wells.
John Collier & Sons	1913	30 h.p. motor			Alfalfa	Pumps from Sacramento River.
Johnson & Bueri	1913	20 h.p. motor			Alfalfa	Pumps from Sacramento River.
Yolo Orchard Company	1913	100 h.p. motor	12 in. centrifugal	Belt	Fruit and alfalfa	Pumps from sump receiving water from Cache Creek through siphon.
Roy Coil	1913	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa and fruit.	
Fred Kent	1913	20 h.p. motor	7 in. centrifugal	Belt	Alfalfa.	
A. Chivino	1913	10 h.p. motor	4 in. centrifugal	Belt	Vegetables.	
Ned Kerr	1913	7½ h.p. motor	3 in. centrifugal	Belt	Alfalfa and vegetables.	
H. J. N. Rasmussen	1913	5 h.p. motor	2 in. centrifugal	Belt	Vegetables and fruit	Includes domestic use.
C. N. Faris	1914	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa.	
Martinelli & Co.	1914	20 h.p. motor	6 in. centrifugal	Belt	Vegetables	Gas engine had been used for several years previously.
O. A. Lowe	1914	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa	5 wells.
Geo. Zane	1914	5 h.p. motor	2 in. power		Vegetables	Includes domestic use.
C. P. Green	1914	25 h.p. motor	7 in. centrifugal	Belt	Alfalfa.	
C. H. Steinberg	1914	20 h.p. motor	7 in. centrifugal	Belt	Alfalfa.	
R. B. Green	1914	10 h.p. motor	4 in. centrifugal	Belt	Alfalfa and fruit.	

L. L. Williams	1914	5 h.p. motor	2 in. centrifugal	Belt	Vegetables and fruit.	
Wm. Morton	1914	7½ h.p. motor	3 in. centrifugal	Belt	Vegetables.	
Emil Simon	1914	20 h.p. motor	6 in. centrifugal	Belt	Alfalfa.	
W. H. Browning	1914	5 h.p. motor	2 in. centrifugal	Direct	Fruit	Includes domestic use.
Jas. Purrington	1914	5 h.p. motor	2 in. centrifugal	Belt	Fruit	Includes domestic use.
J. D. Stevens	1914	5 h.p. motor	2 in. centrifugal	Direct	Fruit	Includes domestic use.
H. P. Eakle	1914	15 h.p. motor	6 in. centrifugal	Belt	Alfalfa and vegetables	Gas engine used previously. Includes domestic use.
G. B. Isham	1914	5 h.p. motor	2 in. centrifugal	Belt	Fruit	Includes domestic use.
G. A. Jordan	1914	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa.	
Herman Roth	1914	50 h.p. motor	10 in. centrifugal	Direct	Alfalfa.	
T. Oliver	1914	5 h.p. motor	2 in. centrifugal		Alfalfa.	
M. E. Dole	1914	15 h.p. motor			Alfalfa.	

COST OF IRRIGATING AND HANDLING ALFALFA IN SACRAMENTO VALLEY IN 1914.

Records were kept in 1914 of the cost of irrigating and handling alfalfa in the sections of Sacramento Valley where alfalfa duty of water determinations were being made. The items included covered the cost of cutting, raking, shocking, stacking and baling. The average total cost of the first four of these items was $1.88 per ton. The cost of baling in Sacramento Valley ranges from $2 to $2.25 per ton. The prevailing prices of labor in Sacramento Valley are $2 to $2.50 per day per man and $1 per head for stock. The usual price for a man applying water is 25 cents per hour. The full data, with averages for the separate sections and for all of them together, are summarized in the table below.

It should be borne in mind that it is not fair to compare the total irrigation and handling cost per acre for the various sections covered in the investigation without analyzing the data contained in the tables for each particular section. For instance, the highest cost per acre was at Woodland, due principally to the higher charge there for water. The lowest cost was at Willows, where it was found more profitable to pasture the fields after two or three crops had been removed. The cost of applying water at Orland was about double that in other sections, owing to the larger number of irrigations given there. The usual price received for alfalfa in 1914 was $4 per ton for loose hay and $6.50 per ton for baled hay.

TABLE 36.

COST OF IRRIGATING AND HANDLING ALFALFA, SACRAMENTO VALLEY, 1914.

Section	Reference number of tract	Annual cost of irrigation per acre		Total cost of handling crop, per ton of hay						Total seasonal cost of handling crop, per acre	Total of all irrigation and handling costs, per acre	Notes
		Applying water, including clearing of ditches where this is a factor	Water charges, or cost of pumping	Cutting	Raking	Shocking	Stacking	Baling	Moving baled hay			
Woodland	1	$0 60	$3 95	$0 33	$0 17	$0 19	$0 86	$2 15	$0 50	$18 33	$22 88	2 irrigations; 5 cuttings.
Woodland	2			20	09	27	1 04			5 06	5 06	Not irrigated; three crops raised.
Woodland	3	45	1 84	29	16	16	34	2 15	47	11 76	14 05	2 irrigations; 5 cuttings; buck rake used in stacking.
Woodland	4			35	16	22	77			5 35	5 35	Not irrigated; three cuttings.
Woodland	5	1 92	10 56	39	19	18	72			7 20	19 68	3 irrigations; 5 cuttings; pumping plant.
Woodland	6	40	1 31	33	15	26	80	2 15	1 00	19 12	20 83	1 irrigation; five cuttings; baled hay hauled to car.
Woodland	7	1 11	2 52	23	10	21	87	2 15	1 00	27 66	31 29	2 irrigations; 5 cuttings; baled hay hauled to car.
Woodland	8	32	1 63	25	17	18	1 08			5 46	7 42	2 irrigations; 4 cuttings.
Woodland	9	1 65	5 23	27	13	21	59	2 00	29	15 16	22 04	3 irrigations; 5 cuttings; pumping plant.
Average		$0 92	$3 86	$0 28	$0 14	$0 20	$0 79	$2 14	$0 65	$12 79	$16 51	
Los Molinos	1	$1 50	$2 00	$0 39	$0 19	$0 23	$1 07			$12 42	$15 92	4 irrigations; 5 cuttings.
Los Molinos	2	1 62	2 00	73	29	37	1 02			10 86	14 44	6 irrigations; 6 cuttings.
Los Molinos	3	1 37	2 00	53	22	27	97			9 64	13 01	6 irrigations; 5 cuttings.
Los Molinos	4	1 74	2 00	50	16	27	48			8 58	12 32	4 irrigations; 5 cuttings.
Los Molinos	5	1 97	2 00	33	16	18	86			12 77	16 74	4 irrigations; 5 cuttings.
Los Molinos	6	1 44	2 00	52	26	26	52			7 84	11 28	5 irrigations; 6 cuttings.
Average		$1 61	$2 00	$0 50	$0 21	$0 26	$0 82			$10 35	$13 95	
Orland	1	$2 27	$2 00	$0 44	$0 22	$0 57	$0 60			$9 22	$13 49	7 irrigations; 5 cuttings.

TABLE 36—Continued.

COST OF IRRIGATING AND HANDLING ALFALFA, SACRAMENTO VALLEY. 1914.

Section	Reference number of tract	Annual cost of irrigation per acre		Total cost of handling crop, per ton of hay						Total seasonal cost of handling crop, per acre	Total of all irrigation and handling costs, per acre	Notes
		Applying water, including cleaning of ditches where this is a factor	Water charges, or cost of pumping	Cutting	Raking	Shocking	Stacking	Baling	Moving baled hay			
Orland	2	3 00	2 00	58	24	-------	1 02	-------	-------	11 32	16 32	18 irrigations; 5 cuttings; cost of raking includes bunching with rake.
Orland	3	1 73	2 00	57	23	26	81	-------	-------	10 90	14 63	8 irrigations; 5 cuttings.
Orland	4	2 10	2 00	55	30	33	96	-------	-------	13 19	17 19	13 irrigations; 5 cuttings.
Orland	5	2 93	2 00	64	26	37	1 03	-------	-------	13 13	18 06	13 irrigations; 5 cuttings.
Orland	6	2 35	2 00	61	27	30	94	-------	-------	11 15	15 50	9 irrigations; 4 cuttings.
Orland	7	61	2 00	32	11	24	88	-------	-------	11 31	13 92	3 irrigations; 4 cuttings.
Average	-------	$2 14	$2 00	$0 53	$0 23	$0 34	$0 89	-------	-------	$11 46	$15 59	
Willows	1	$1.13	$1.50	$0 52	$0 26	$0 32	$1 11	-------	-------	$9 43	$12 06	10 irrigations; 5 cuttings.
Willows	2	1 01	1 50	75	46	30	1 30	-------	-------	4 84	7 35	9 irrigations; 3 cuttings.
Willows	3	87	1 50	52	28	-------	1 20	-------	-------	8 25	10 62	4 irrigations; 3 cuttings. Cost of raking includes bunching with rake.
Willows	4	1 90	1 50	1 00	57	-------	1 02	-------	-------	4 21	7 61	6 irrigations; 3 cuttings.
Willows	5	1 83	1 50	66	30	-------	1 10	-------	-------	7 32	10 65	4 irrigations; 5 cuttings.
Willows	6	78	3 00	57	27	28	79	-------	-------	9 34	13 12	7 irrigations; 4 cuttings; pumping plant.
Average	-------	$1 25	$1 75	$0 67	$0 36	$0 30	$1 09	-------	-------	$7 23	$10 23	
General average	-------	$1 48	$2 40	$0 49	$0 23	$0 27	$0 89	-------	-------	$10 45	$14 07	

INVESTIGATIONS IN SOUTHERN CALIFORNIA.

As heretofore reported, irrigation investigations in southern California are conducted through a special field division under the immediate direction of Mr. C. E. Tait, irrigation engineer. During a portion of the biennium Mr. Tait has been assisted by Wells A. Hutchins, field assistant, and Frank J. Veihmeyer, assistant irrigation engineer. Cooperative relations have been established with the Imperial Valley Experimental Farm of the University of California, of which Walter E. Packard, working under the direction of Professor J. W. Gilmore, head of the division of agronomy of the College of Agriculture, is superintendent. The following data regarding work in southern California are taken from a report submitted by Mr. Tait:

Investigations of Duty of Water in Imperial Valley.—Experiments were begun early in 1914, in cooperation with the University of California, to measure the duty of water in Imperial Valley and to determine what becomes of the water applied in irrigation. It is the intention that these experiments shall cover a period of two or more years for each crop studied. The field work during 1914 has been conducted by F. J. Veihmeyer, assistant irrigation engineer, working in conjunction with Walter E. Packard, superintendent of the Imperial Valley Experiment Station of the University of California.

It is generally realized that a knowledge of the duty of water in Imperial Valley is of much value, not only to that section but to others in California and throughout the southwest. Land holdings there are large and water is comparatively cheap, consequently much of the irrigation in the past has been carelessly done. This section has some peculiar conditions not generally found in the irrigated districts throughout the West. The soils are tight and they take water slowly. The irrigation season extends throughout the year. The summers are very hot, the atmosphere is dry, and evaporation is excessive. With rather meagre information regarding the water requirements of plants in such a country, the contracts between the California Development Company and the Imperial mutual water companies established 4 acre-feet per acre as the limit of average use of water in the territories of the mutual companies. The United States Government accepted this standard in fixing the requirements for making final proof for the lands under the Desert Act. A few years ago Imperial Water Company No. 1, in order to expand its irrigated area, amended its by-laws, making 4 acre-feet sufficient for 1¼ acres of land. The economical use of water is to be urged in view of danger of damage to the land following an excessive use of water, the possibility of extending the irrigated area without increasing the supply of water, and the direct saving to the land owners in the purchase of water.

In 1906 the average use of water on 120,000 acres of land under Imperial water companies Nos. 1, 4, 5, and 7 was 2.04 acre-feet per acre. At that time a large portion of the land was growing barley as a temporary crop. Much of the barley has now given place to alfalfa, cotton, and cantaloupes. Many of the barley growers use only 1 acre-foot per acre, as shown by the water company charges. Alfalfa requires more water than any other crop, and the company records indicate that from 3 to 4 acre-feet is used for its production. The change from grain to alfalfa has brought an increased use of water and the average duty in 1913 was approximately 2.25 acre-feet per acre. It has also brought about a different distribution of the water throughout the year. During the early period the maximum use was in March, when alfalfa, barley, melons, and almost every crop grown except corn was given water. The maximum use in 1913 was in July, when alfalfa must be given a plentiful supply.

It is fortunate that the maximum use of water in Imperial Valley so nearly corresponds with the peak of the annual flow in Colorado River, which occurs year after year, without fail, during the latter half of June.

Mr. R. S. Carberry, superintendent of Imperial Water Company No. 1, states in his annual report for 1912 that seventeen typical farms in the No. 1 territory were selected from which to determine the duty of water for the leading crops, as shown by the companies' water deliveries. The averages in acre-feet of water applied per

acre were: Alfalfa, 4.19; corn, 2.18; cantaloupes, 1.62, and barley, 1.00. Imperial Water Company No. 7 determined the average amount used for alfalfa in its district during 1913 from the water charges to be from 3.5 to 4 acre-feet per acre.

Imperial Valley has a great range of crops that can be grown and some uncertainty yet remains as to what will become established, but alfalfa will no doubt continue to be one of the standards.

The measurements on duty of water now being conducted are primarily to measure the amounts applied to alfalfa, although some measurements may be secured for other crops without interference with the measurements for alfalfa. The tracts selected for measurement represent the several predominating types of soil. The water applied to each tract is being measured in the supply ditch by weir or rating flume, with recording instrument giving a continuous record. Some difficulty was experienced in selecting tracts to fulfill all the requirements. It was desirable to work only on tracts where the alfalfa was to be cut for hay. A large majority of the alfalfa in Imperial Valley is pastured. It was necessary that the proper conditions for measurement be found in the supply ditch.

The procedure followed in the Imperial Valley duty of water studies is similar to that followed in duty of water studies in Sacramento Valley. In addition to water measurement, each tract has been surveyed and platted, and the following is being noted: Time and duration of each irrigation; size of stream used per "land" or border check; time required for water to reach lower end of land; drainage facilities, appearance of crop, etc.

In order to ascertain the disposition of the water applied, the percentage of moisture in the soil is being determined for each tract on which the water applied is being measured. Borings with soil auger are made at the upper, middle, and lower portions of two lands on each tract before and after each irrigation. Soil samples are taken at the middle of each foot in depth from these holes down to the sixth foot, or farther if moisture extends below that depth. The percentage of moisture is found by weighing and drying the soil samples, the percentage being calculated on the basis of the weight of the dry soil. The experiments are now being conducted on the farms of John Waterman, W. C. Stearns, Allen Davison, J. W. Smith, and C. R. Wheelock.

Investigations of Water Companies.—The investigation of mutual water companies conducted for several seasons with interruptions due to other work has been continued and extended to cover public service companies supplying water for irrigation.

Investigations of Wells and Seepage in Imperial Valley.—Two special investigations were conducted in Imperial Valley during the winter of 1913–14, one being the collection of data on the wells and underground waters of the valley and Colorado Desert, and the other a general survey of the valley to secure accurate information on the cause and extent of seeped or water-logged lands which were apparent in certain localities. The purpose of each investigation was twofold; each furnished results of public interest and scientific value as independent projects, while at the same time each was a desirable preliminary to the more extended work being begun on duty of water and soil moisture. The full data on seepage conditions are being held for further study in connection with other investigations, but a summary of the data is given below. The full report on wells, with map, is submitted as an appendix hereto. This report has been prepared under the direction of Mr. Tait by Wells A. Hutchins, by whom the field investigations were made.

The investigations of injury from excessive irrigation water in Imperial Valley were carried on under the direction of Mr. Tait by Frank J. Veihmeyer, assistant irrigation engineer, in conjunction with Walter E. Packard, superintendent of the Imperial Valley Experimental Farm of the University of California. The purpose was to gain a knowledge of the action in the soil of the water applied by irrigation, with a view to determining the best method of so using water that danger will not result.

The crops in certain portions of Imperial Valley have been injured by the formation of a water table, or by saturation of the soil and subsoil. Certain sections, as the slope near the mesa along No. 5 canal on the east side of the valley, and the

bluffs on the west side of Mesquite Lake basin, showed an outcropping of moisture and resultant excess of alkali before irrigation began. In some of these originally affected areas benefit has resulted from irrigation through washing the salts downward, while some of the lands on the edge of the Mesquite Lake basin which were unfit for agricultural purposes in their desert state are now also growing crops. But along No. 5 canal, and in some other places, the application of water, together with seepage from the canal, has apparently aggravated the trouble.

Numerous studies have been made of the soils of Imperial Valley and their character is well known. As pointed out by Mr. Tait, the land was formed as the delta of Colorado River and consequently the soil had its origin in the fine particles of silt which had been carried a long distance by a sluggish current. This accounts for the tightness of the soil and lack of ability to take up moisture readily. The tight soil predominates through the central portion of the valley, but as the slopes are approached on both the east and the west sides, the soil grades to a more sandy type, owing to the intermingling of mountain wash with river sediment.

From the data gathered by Mr. Tait and Mr. Veihmeyer both the clay and the clay loam soils of Imperial Valley have been found to be deficient in absorptive power, while even the loose, sandy soils are so fine in texture that they do not take up moisture as readily as sandy soils elsewhere in the arid region. They have found that moisture sometimes does not reach more than 18 or 24 inches deep in the hard soil after irrigation has been followed for an entire season. On the other hand, it frequently reaches to depths of 10 feet or more in the soft soils. Where the movement of the irrigation water depends on a subsoil of such varying degree of porosity, it is evident that the same method of irrigation should not be followed on all land, but that each type of soil should receive a special treatment. Thus it appears, as Mr. Tait points out, that a knowledge of the subsoil and of the movement of irrigation water should be regarded by the irrigator as invaluable. Land owners know from experience that the hard soils do not retain moisture long and that they must be irrigated frequently with small amounts of water to maintain a proper and uniform condition for good crop production. On the other hand, they find that the intervals between irrigations may be much longer in the case of the soft soils, provided a plentiful amount of water is applied. Thus far most of the irrigators have been guided mainly by the condition of the crops grown and by what is apparent on the surface only; they seldom have any definite knowledge of the condition of the subsoil or the depth to which irrigation water penetrates it.

In reviewing the report of investigations by Mr. Veihmeyer, Mr. Tait advises that in Imperial Valley, as elsewhere, a surface layer of soft soil underlaid with a hard layer may absorb moisture until there is an accumulation or surplus on top of the hard layer, completely saturating the lower portion of that top layer. If water continues to be applied in excess or at a rate greater than the downward movement, this local water table rises. If it approaches to within 2 or 3 feet of the surface and the surface becomes dry, moisture will arise by capillarity and bring with it alkali. This condition exists in some of the localities investigated.

Mr. Tait finds that the damage to the lands in the district supplied by Imperial Water Company No. 5 is due in part to a condition which existed before irrigation was practiced and in part to seepage from the east side canal. Moisture absorbed from rainfall on the east mesa, he states, apparently percolates westward, following the slope of strata which bring it to or near the surface along the canal. The soils there are of the sandy type, the surface generally being overlaid by a hard stratum. This hard stratum arrests the downward movement of seepage water from the canal itself and the water must find an outlet at the surface on the slope below the canal.

Throughout most of Imperial Valley, however, Mr. Tait finds that trouble of the nature described above has not been experienced. He states that if water can be applied to the land in amounts sufficient to produce a good growth of plant and crop, yet so sparingly as to prevent an accumulation of moisture in any part of the subsoil, there need be no fear of damage to lands throughout the valley by seepage and alkali; while those areas that have been damaged in a large measure through

a natural condition existing without irrigation may be reclaimed by special methods.

The problem of preventing seepage of land and its resultant damage by alkali is very largely one of the proper and economical use of irrigation water and it was in this relation to the use of water that this investigation was undertaken by Mr. Tait. The information obtained should enable a more intelligent application of water than has been practiced heretofore, and it gives a record of a condition, to be checked by further investigation in the future, which will plainly determine whether the damage is merely of local nature and extent in certain portions of the valley or whether it will likely become general.

Irrigation Development in Southern California.—In connection with other duties in irrigation investigations, an effort is made to keep in touch with the general progress of California irrigation development. Mr. Tait submits the following statement from southern California:

"Among the more important developments now in progress in southern California are the activities of a number of the cities toward securing increased water supplies for future growth and for leasing water for irrigation until its use by the cities becomes necessary. The largest of these undertakings, the Los Angeles aqueduct, is now completed. The aqueduct furnishes enough water for the irrigation of 135,000 acres of land on the basis of 1 miner's inch for 7.5 acres, the average duty of water near the city, where the crops include citrus, deciduous and small fruits, walnuts, garden truck and alfalfa. Plans for the utilization of the water brought by the aqueduct from Owens River have not matured as rapidly as was anticipated, but steps are now being taken by land owners in San Fernando and other valleys adjacent to the city to perfect district organizations for the use of the water by irrigation.

"San Diego is now engaged in a movement to secure a more adequate water supply for the future. The reservoir and distributing system of the Southern California Mountain Water Company have been purchased by the city. This includes Moreno and Upper and Lower Otay reservoirs and Barrett reservoir site on which the city may construct a storage dam. Plans are now being discussed for the purchase of water rights, reservoir sites and rights of way for making the surplus flood waters of San Diego and San Luis Rey rivers available for use by the city.

"Santa Barbara is another city that has adopted the policy of building in advance of actual necessity. A tunnel to serve the dual purpose of collecting seepage waters and of a conduit for water from Santa Ynez River to Santa Barbara, was recently completed through the Santa Ynez range. Gibralter dam is now being constructed on the river to impound flood waters which may be drained through the tunnel to the city and valleys bordering Santa Barbara Channel.

"No irrigation projects of great magnitude have been instituted in the coastal region during the past two years, but interest has been stimulated in the storage of flood waters in connection with flood protection. Storm waters are spread over the the gravel beds stretching below the canyons of the more important streams to bring about the absorption of the waters to augment the subterranean reservoirs being drawn on by pumping from wells. This kind of storage is practiced on Santa Ana River and on Lytle, San Antonio, and Santiago creeks, and similar work is contemplated for San Gabriel and San Jacinto rivers. This work has resulted in much benefit to the agricultural sections relying on underground waters fed from these streams for irrigation. The possibility of impounding flood waters by dams in mountain canyons is being seriously discussed for San Gabriel River and streams in San Diego County."

The irrigated area continues to be gradually extended by the installation of new pumping plants by small cooperative companies and by individuals. Figures furnished by manufacturers of pumps indicate that about 3,000 pumping plants have been installed in the eight southern counties since 1910. Localities where development of this kind is most conspicuous are San Jacinto Valley, West Riverside, Chino, Ventura County and several valleys in San Diego County. Lands in the mountain or elevated orchard districts, such as Victor, Antelope, Yucaipa, and other valleys situated at elevations of 2,500 to 4,000 feet above sea level, are being rapidly

settled or taken up under the Desert Act. Settlers in Victor Valley are making concerted effort to secure government aid for the reclamation of their lands and to consummate a plan for turning the water stored by Arrowhead Reservoir to their lands on the Mojave Desert.

The largest addition to the irrigated area of southern California during the past two years is in Palo Verde and Imperial valleys, where water for irrigation is taken by canals from Colorado River. Palo Verde Valley now has its canal system constructed to cover 45,000 acres and the Palo Verde Mutual Water Company reports that about one half of this area is now being irrigated. Extensions to the canal system of Imperial Water Company No. 5 and the construction of a system by Imperial Water Company No. 3 are adding 100,000 acres to the area already reclaimed in Imperial Valley. This land should receive water within a few years.

Improvement in the character of construction of irrigation works is conspicuous. Some of the canals now being constructed in Imperial Valley are being lined with concrete, a practice that has heretofore been considered too costly for that region. The pumping districts near the coast have been benefited by reductions in rates for electrical power and by the extension of service lines of power companies giving more competition. Gasoline, distillate, and oil engines have been much improved within the last few years and they now permit the use of low grades of fuel oils, giving power for pumping at small cost. Turbine and deep well pumps have been perfected and adapted to the requirements of high pumping lifts, with benefits to sections where the ground water has receded.

MISCELLANEOUS DATA ON DUTY OF WATER.

Below are given a number of tables summarizing data on the duty of water in California that have been gathered from time to time, either through original investigation by this office or by search of reports of other investigations. Part of the figures given have already been printed in reports of this office; they are included, however, in order to have assembled in one report all such data collected to date.

TABLE 37.

Summary of miscellaneous data on gross duty of water.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Gross duty, acre-feet per acre	Notes
Shasta Valley:				
Little Shasta River	1912	4,498	4.20	Meadow and pasture.
Modoc County:				
Pit River Ditch and Dam Co.[1]	1910	960	4.16	Alfalfa, 300 acres; grain, 300 acres; meadow, 350 acres.
Lassen County:				
Lassen Irrigation Co.[1]	1910	5,000	2.34	Mostly alfalfa.
Owens Valley:				
Owens River Canal[2]	1904	7,000	2.19	Alfalfa, grain, grass.
Bishop Creek Canal[2]	1904	8,000	4.31	Alfalfa, 1,500 acres; grain, 1,200 acres; pasture, 4,000 acres; orchards, 60 acres; miscellaneous, 1,240 acres.
Farmers' Canal[2]	1904	1,800	5.79	Alfalfa, 500 acres; pasture, 1,300 acres.
McNally Canal[2]	1904	7,000	2.69	Mostly grass.
Bishop Creek Association[2]	1904	6,600	1.23	
Rawson Canal[2]	1904	4,000	2.88	
Dell Canal[2]	1904	1,300	5.95	Alfalfa, grain, grass.
Owens River and Big Pine Canal[2]	1904	4,000	4.31	Alfalfa, 1,600 acres; pasture, 1,700 acres; grain, 700 acres.
Stevens Canal[2]	1904	2,400	2.58	Alfalfa, grain, grass.
Average			4.82	
Owens River[3]	1909	3,010	8.60	Alfalfa, grain, truck, vines, and miscellaneous.
Placer County:				
South Yuba Water Co.[1]	1909	6,900	7.74	Deciduous fruits.
Bear River Water Co.[1]	1909	5,000	5.82	Deciduous fruits.
Gold Hill Water Co.[1]	1909	2,000	4.02	Deciduous fruits.
Sacramento Valley:				
South Feather Land and Water Co.	1912	1,200	5.83	Oranges, olives, and deciduous fruits.
Palermo Land and Water Co.	1912	1,900	6.06	Oranges, olives, peaches, and garden truck.
Sutter-Butte Canal Co.	1912	14,000	7.53	Rice, alfalfa, deciduous fruits, and miscellaneous.
Stony Creek Irrigation Co.[4]	1908	703	6.94	Mostly alfalfa.
Orland Project[4]	1910	703	6.82	Mostly alfalfa.
Orland Project[4]	1911	2,663	14.72	Mostly alfalfa.
Orland Project[4]	1912	4,230	8.05	Mostly alfalfa.
Orland Project[4]	1913	6,616	6.12	Mostly alfalfa.
Sacramento Valley Irrigation Co.[5]	1910	3,448	9.80	Mostly alfalfa.
Sacramento Valley Irrigation Co.[5]	1911	5,800	6.02	Mostly alfalfa.
Colusa Irrigation Co.[1]	1909	300	3.08	Alfalfa.
Moore Canal	1907	6,958	3.15	Mostly alfalfa.
San Joaquin Valley:				
Modesto Canal	1904	6,895	13.18	Alfalfa, deciduous fruits and miscellaneous.
Modesto Canal[6]	1905	10,500	7.42	Alfalfa, deciduous fruits and miscellaneous.
Modesto Canal[6]	1906	12,685	6.93	Alfalfa, deciduous fruits and miscellaneous.
Modesto Canal[6]	1907	14,020	9.01	Alfalfa, deciduous fruits and miscellaneous.
Modesto Canal[6]	1909	22,136	6.85	Alfalfa, 16,306 acres; orchards, 561 acres; vines, 2,404 acres; miscellaneous, 2,865 acres.
Modesto Canal	1912	38,247	3.85	Alfalfa, orchards, vines, grain, garden, beans, and corn.
Turlock Canal	1904	20,000	8.34	Alfalfa, deciduous fruits and miscellaneous.

[1]Data from census 1910.
[2]Measurements by U. S. Geol. Survey.
[3]Measurements by C. H. Lee.
[4]Data from U. S. Recl. Service.
[5]Data from company.
[6]Data from district.

TABLE 37—Continued.

Summary of miscellaneous data on gross duty of water.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Gross duty, acre-feet per acre	Notes
Turlock Canal [6]	1905	28,100	4.66	Alfalfa, deciduous fruits, and miscellaneous.
Turlock Canal[6]	1906	32,587	6.32	Alfalfa, deciduous fruits, and miscellaneous.
Turlock Canal[6]	1907	47,803	3.95	Alfalfa, deciduous fruits, and miscellaneous.
Turlock Canal[6]	1909	47,843	4.84	Alfalfa, 27,136 acres; orchards, 5,458 acres; vines, 4,796 acres; miscellaneous, 10,453 acres.
Turlock Canal[6]	1910	64,791	1.95	Alfalfa, 41,845 acres; orchards, 6,143 acres; vines, 4,235 acres; miscellaneous, 12,538 acres.
Turlock Canal[6]	1911	71,106	3.45	Alfalfa, 49,751 acres; orchards, 6,295 acres; vines, 3,802 acres; miscellaneous, 11,258 acres.
Turlock Canal	1912	96,900	2.52	Alfalfa, orchards, vines, potatoes, grain, melons, corn, and miscellaneous.
Madera Canal	1912	10,597	2.68	Alfalfa, orchards, and miscellaneous.
Oakdale and South San Joaquin Canal	1912	3,550	9.53	Alfalfa, orchards, and gardens.
Miller & Lux canals	1912	55,700	2.46	Alfalfa, 13,000 acres; grain, 3,700 acres; pasture, 39,000 acres.
James pump, Fresno Slough	1912	4,402	.58	Alfalfa, 1,232 acres; grain, 2,561 acres; pasture, 111 acres; other, 498 acres.
Helm Ditch	1912	1,550	1.08	Alfalfa, 950 acres; grain, 600 acres.
San Joaquin and Kings River Canal	1912	163,350	2.75	Miscellaneous crops.
Blythe Canal	1912	8,000	3.08	Pasture.
East Side Canal	1912	46,500	2.05	Alfalfa, 2,250 acres; grain, 1,000 acres; pasture, cropped, 3,705 acres; deciduous orchards, 175 acres; vines, 15 acres; miscellaneous, 4,355 acres; flooded grazing land, 35,000 acres.
Patterson pump	1912	6,200	2.00	Alfalfa, deciduous fruits, citrus fruits, grain, orchards and alfalfa, orchards and miscellaneous. Record of diversion is close approximation.
East Side Canal	1909	6,000	3.45	Alfalfa, grain and miscellaneous.
Kern County:				
Farmers' Canal, Kern County[5]	1909	7,000	7.95	Alfalfa, grain and miscellaneous.
Wasco, Fourth Extension Canal[5]		1,940	2.58	Alfalfa, grain and miscellaneous.
Santa Clara Valley:				
Pioneer Canal	1904	900	3.34	Mostly prunes and alfalfa.
Pioneer Canal	1912	200	4.39	Mostly prunes and alfalfa.
Statler Canal	1904	1,961	1.58	Mostly prunes and alfalfa.
Sorosis Canal	1904	3,021	1.75	Mostly prunes and alfalfa.
Sorosis Canal	1912	150	2.67	Mostly prunes and alfalfa.
Kirk Canal	1912	415	2.29	Mostly prunes and alfalfa.
Paul Masson Canal	1912	45	7.67	Mostly prunes and alfalfa.

[5]Data from company.
[6]Data from district.

TABLE 37—Continued.

Summary of miscellaneous data on gross duty of water.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Gross duty, acre-feet per acre	Notes
Santa Clara River Valley:				
Camulos Ditch	1912	400	1.27	Alfalfa, 150 acres; deciduous fruits, 190 acres; citrus fruits, 60 acres.
Hardgrave & Comfort Ditch	1912	470	5.50	Alfalfa, 115 acres; citrus fruits, 5 acres; miscellaneous, 350 acres.
Piru Water Co.	1912	376	3.77	Deciduous fruits, 160 acres; citrus fruits, 216 acres.
South Side Improvement Co.	1912	1,400	.76	Deciduous fruits, 700 acres; citrus fruits, 700 acres.
Stringtown & Carmicle Ditch	1912	350	5.87	Alfalfa.
Sespe Land and Water Co.	1912	40	15.10	Alfalfa.
Fillmore Irrigation Co.	1912	1,674	2.00	Alfalfa, 58 acres; deciduous fruits, 119 acres; citrus fruits, 1,497 acres.
Hardison Ranch Co.	1912	109	1.39	Alfalfa, 2 acres; citrus fruits, 90 acres; vineyard, 2 acres; miscellaneous, 15 acres.
Turner Ditch	1912	187	7.93	Alfalfa, 12 acres; deciduous fruits, 62 acres; citrus fruits, 74 acres; beans, 37 acres; miscellaneous, 2 acres.
Atmore Ditch	1912	150	4.65	Alfalfa, 110 acres; deciduous fruits, 25 acres; citrus fruits, 15 acres. Seasonal flow estimated.
Interurban Land and Water Co. (Carmicle Ditch)	1912	1,112	1.34	Alfalfa, 350 acres; deciduous fruits, 380 acres; citrus fruits, 354 acres; beans, 28 acres.
Santa Clara Water and Irrigation Co. (Farmers' Ditch)	1912	1,734	2.70	Alfalfa, 40 acres, deciduous and citrus fruits, 348 acres; beans, 893 acres; miscellaneous, 116 acres; other, 334 acres.
Interurban Land and Water Co. (River Street Ditch)	1912	1,536	2.32	Alfalfa, 200 acres; deciduous fruits, 1,266 acres; citrus fruits, 20 acres; beans, 50 acres.
Santa Paula Water Works	1912	1,628	1.89	Deciduous fruits, 880 acres; citrus fruits, 748 acres.
Santa Clara Water and Irrigation Co. (Saticoy division)	1912	4,414	1.42	Alfalfa, 173 acres; deciduous fruits, 374 acres; citrus fruits, 155 acres; beans 3,601 acres; miscellaneous, 111 acres.
Santa Ana River Valley:				
Old Town Ditch	1912	2,700	2.45	Citrus fruits.
Crafton Water Co.	1912	1,800	2.43	Citrus fruits.
Bear Valley Mutual Water Co.	1912	15,000	2.00	Citrus fruits.
City Creek Water Co.	1912	320	2.11	Citrus fruits.
Average			2.11	
McKenzie Ditch	1912	432	2.04	Alfalfa and truck.
Shay Ditch	1912	175	3.71	Alfalfa and truck.
Warm Creek	1912	200	6.45	Mostly alfalfa.
Average			3.50	
Fontana Development Co. et. al.	1912	15,000	1.31	Citrus fruits, 12,800 acres; alfalfa, 800 acres; miscellaneous, 1,400 acres.
Average			1.31	

TABLE 37—Continued.

Summary of miscellaneous data on gross duty of water.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Gross duty, acre-feet per acre	Notes
Riverside Water Co.	1912	9,000	2.91	Citrus fruits, 4,500 acres; alfalfa, 3,900 acres; miscellaneous, 258 acres; other, 342 acres.
Jurupa Canal	1912	785	2.96	Citrus fruits, 120 acres; alfalfa, 465 acres; miscellaneous, 200 acres.
Gage Canal Co.	1912	9,040	1.83	Citrus fruits. Diversion estimated.
Alvitrez Ditch	1912	800	3.43	Alfalfa and truck.
Average			2.44	
Lower Legage Ditch	1912	150	4.01	Mainly alfalfa.
Upper Legage Ditch	1912	75	4.00	Mainly alfalfa.
Durkee Ditch	1912	300	4.00	Mainly alfalfa.
Fraser Ditch	1912	100	4.00	Alfalfa and truck.
Euqua Ditch	1912	200	3.00	Alfalfa.
Average			3.76	
Santa Ana River Valley:				
Santa Ana Valley Canal	1912	17,000	1.91	Citrus fruits, walnuts, apricots, and miscellaneous.
Anaheim Union Canal	1912	13,000	2.07	Citrus fruits, walnuts, and miscellaneous.
Average			1.93	
Southern California:				
California Domestic Water Co.	1909	10,000	2.17	Oranges, lemons, and walnuts.
Euclid Avenue Water Co.	1909	165	1.30	Oranges.
Imperial Valley:				
Colorado River[7]	1906	127,423	1.89	Barley, 102,000 acres; alfalfa, 13,500 acres; cantaloupes, 1,175 acres; grapes, 450 acres; miscellaneous, 10,298 acres.
Imperial Water Co. No. 1[7]	1906	70,000	1.81	Alfalfa, barley, vines, corn, and truck.
Imperial Water Co. No. 1[7]	1910	90,911	2.60	Alfalfa, 43,503 acres; grain, 27,004 acres; vines, 1,539 acres; miscellaneous, 18,835 acres.
Imperial Water Co. No. 1[7]	1911	99,572	2.76	Alfalfa, 44,232 acres; grain, 28,897 acres; vines, 1,352 acres; miscellaneous, 25,031 acres.
Imperial Water Co. No. 1[7]	1912	100,681	3.16	Alfalfa, 47,116 acres; grain, 26,241 acres; vines, 926 acres; miscellaneous, 26,398 acres.
Imperial Water Co. No. 1[7]	1913	100,681	3.35	Alfalfa, 59,279 acres; barley, 19,257 acres; corn, 12,933 acres; cotton, 4,741 acres; melons, 3,125 acres; asparagus, 371 acres; vines, 910 acres; other, 75 acres.
Imperial Water Co. No. 4[7]	1906	15,000	1.62	Cantaloupes, alfalfa, barley, corn, and truck.
Imperial Water Co. No. 4[7]	1913	17,500	3.38	Cantaloupes, alfalfa, barley, corn, vegetables, and fruits.
Imperial Water Co. No. 5[7]	1906	25,000	2.62	Alfalfa, corn, and barley.
Imperial Water Co. No. 5[7]	1913	47,025	4.21	Alfalfa, cotton, corn, barley, and miscellaneous.
Imperial Water Co. No. 6[7]	1913	17,300	2.95	Barley, cotton, corn, and alfalfa.
Imperial Water Co. No. 7[7]	1906	10,000	2.13	Alfalfa and diversified.
Imperial Water Co. No. 7[7]	1913	16,000	3.82	Alfalfa, 75 per cent; remainder diversified.
Imperial Water Co. No. 8[7]	1913	24,000	3.74	Alfalfa, 50 per cent; melons, cotton, corn, barley, and grapes.
Imperial Water Co. No. 12[7]	1913	12,000	2.51	Cotton, 50 per cent; alfalfa, barley, and corn.
Imperial South Side Water Co.[7]	1913	16,000	2.78	Alfalfa, 50 per cent; corn, cotton, and barley.

[7]Data from company or companies.

TABLE 38.

Summary of miscellaneous data on net duty of water for alfalfa.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Depth of water applied, feet	Notes
Little Shasta Valley:				
Pumping plant, Stallcup farm	1912	310	9.03	
Napa Valley:				
Pumping from Napa Creek	1911	36	2.17	Measurement on Forbes farm.
Sacramento Valley:				
Sutter-Butte Canal Co.	1912	18	2.72	Measurement on Van Note farm.
Stony Creek Irrigation Co.	1907	126	4.50	Measurement on five farms.
Pumping plants at Dixon	1907	68	2.38	Measurement on three farms.
San Joaquin Valley:				
Modesto Canal	1909	80	1.80	Measurement on Beard tract.
Modesto Canal	1910	521	1.90	Measurement on seven farms.
Turlock Canal	1909	609	3.38	Measurement on nine farms.
Pumping plant at Madera	1910	500	4.74	Measurement on Sayre farm.
Pumping plant at Fresno	1910	60	5.10	Measurement on Uridge farm.
San Joaquin and Kings River Canal[1]	1906–7	58,769	1.89	
San Joaquin and Kings River Canal[1]	1907–8	61,197	2.23	
San Joaquin and Kings River Canal[1]	1910–1	68,818	1.72	
San Joaquin and Kings River Canal[1]	1910	534.5	1.75	Covers eleven farms.
San Joaquin and Kings River Canal[1]	1911	235	1.49	Covers seven farms.
San Joaquin and Kings River Canal[1]	1912	633.8	1.95	Covers seven farms.
East Side Canal	1908	1,179.5	1.70	Measurement on eleven farms.
Southern California:				
Riverside Water Co.	1912	10	4.45	Measurement on Harris farms.
Riverside Water Co.	1912	20	4.38	Measurement on H. Harris farm.
Pumping plants at Pomona and Chino	1905	287	2.30	Measurement on seven farms.
Pumping plants at Pomona and Chino	1908	218	2.40	Measurement on seven farms.

[1] Data from company.

TABLE 39.

Summary of miscellaneous data on net duty of water for citrus fruits.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Depth of water applied, feet	Notes
Sierra Foothills:				
Palermo Land and Water Co.	1912	26	.92	
Palermo Land and Water Co.	1912	10.5	1.64	
Palermo Land and Water Co.	1912	11	1.75	
Pleasant Valley Canal	1901	38	1.55	
Lindsay Water Development Co.	1898	510.6	1.00	
Lindsay Water Development Co.	1899	510.6	1.63	
Lindsay Water Development Co.	1900	510.6	1.50	
Lindsay Water Development Co.	1901	510.6	1.14	
Sacramento Valley:				
Stony Creek Irrigation Co.	1907	2	1.76	
Orland Project	1914	10.3	.62	Young oranges.
San Joaquin Valley:				
Pioneer Canal	1901	247	2.00	
Southern California:				
Gage Canal Co., District No. 1[1]	1899	3,959	2.32	
Gage Canal Co., District No. 1[1]	1900	3,614	2.43	
Gage Canal Co., District No. 1[1]	1901	3,614	2.07	
Gage Canal Co., District No. 2[1]	1899	2,871	2.23	
Gage Canal Co., District No. 2[1]	1900	3,237	2.12	
Gage Canal Co., District No. 2[1]	1901	3,237	2.03	
Gage Canal Co., District No. 3[1]	1899	530	1.78	
Gage Canal Co., District No. 3[1]	1900	650	1.63	
Gage Canal Co., District No. 3[1]	1901	650	1.39	
Gage Canal Co., District No. 3[1]	1901	108.3	2.00	
Average[1]			2.00	
Gage Canal Co.[1]	1897	20	1.31	
Gage Canal Co.[1]	1898	30	1.86	
Gage Canal Co.[1]	1899	30	1.59	
Gage Canal Co.[1]	1900	30	1.56	
Gage Canal Co.[1]	1901	30	1.75	
Gage Canal Co.[1]	1902	30	1.64	
Gage Canal Co.[1]	1903	30	1.55	
Gage Canal Co.[1]	1904	30	1.66	
Gage Canal Co.[1]	1905	30	1.19	
Gage Canal Co.[1]	1906	30	1.37	
Gage Canal Co.[1]	1907	30	1.46	
Average			1.54	
Gage Canal and Riverside Water Companies[1]	1899-1905	80,667	2.25	
Riverside Water Co.[1]	1901-1908	9,000	2.29	
Riverside Water Co.	1912	31.5	4.10	
Riverside Water Co.	1912	19	2.58	
Santa Ana Valley Canal	1912	20	1.79	
Santa Ana Valley Canal	1912	18.4	1.52	
Pumping plants at Pomona	1905	319.2	.80	
Del Monte Irrigation Co.[1]	1906	2,000	.73	
Del Monte Irrigation Co.[1]	1907	2,000	1.10	
Del Monte Irrigation Co.[1]	1908	2,000	.73	
Del Monte Irrigation Co.[1]	1909	2,000	.73	
Palomares Irrigation Co.[1]	1906	600	.71	
Palomares Irrigation Co.[1]	1907	600	.83	
Palomares Irrigation Co.[1]	1908	600	.83	
Palomares Irrigation Co.[1]	1909	600	.83	

[1]Data from company.

TABLE 40.

Summary of miscellaneous data on net duty of water for deciduous orchards and vineyards.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Depth of water applied, feet	Notes
Sierra Foothills:				
South Yuba Water Co.[1]	1909	6,900	2.62	
Bear River Canal[1]	1909	5,000	2.32	
Sacramento Valley:				
Palermo Land and Water Co.	1912	33	.75	Prunes.
Palermo Land and Water Co.	1912	10.5	1.64	Olives.
Palermo Land and Water Co.	1912	10	.80	Olives and peaches.
Orland Project	1914	14.2	.25	Young almonds.
Yolo Water and Power Co.	1913	14.2	2.29	Prunes.
San Joaquin Valley:				
Turlock Canal	1909	37.8	.38	One irrigation.
Pumping plants at Madera	1910	222	.86	Two irrigations.
Fresno Canal	1910	160	.49	One irrigation.
San Joaquin and Kings River Canal[1]	1906-1907	104	2.64	
San Joaquin and Kings River Canal[1]	1907-1908	15	2.38	
Pumping plants at Friant	1912	20	.83	Two irrigations.
Pumping plants at Friant	1912	150	.63	
Southern California:				
Santa Ana Valley Canal	1912	15	4.83	Walnuts.
Santa Ana Valley Canal	1912	21	3.18	Walnuts.

[1]Data from company.

TABLE 41.

Summary of miscellaneous data on net duty of water for corn and grain.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Depth of water applied, feet	Notes
Sacramento Valley:				
Yolo Water and Power Co.,[1] and pumping plants	1913	2,419	1.11	Grain.
San Joaquin Valley:				
San Joaquin and Kings River Canal[1]	1906-1907	9,695	.74	Grain.
San Joaquin and Kings River Canal[1]	1907-1908	16,437	.84	Grain.
San Joaquin and Kings River Canal[1]	1906-1907	1,987	2.13	Corn.
San Joaquin and Kings River Canal[1]	1907-1908	2,242	1.65	Corn.
San Joaquin and Kings River Canal[1]	1910-1911	2,385	1.38	Corn.
San Joaquin and Kings River Canal[1]	1910-1911	16,594	.96	Grain.

[1]Data from company.

TABLE 42.

Summary of miscellaneous data on net duty of water for miscellaneous crops.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Depth of water applied, feet	Notes
Modoc County:				
Pit River Ditch and Dam Co.[1]	1910	950	3.75	Alfalfa, 300 acres; grain, 300 acres; meadow, 350 acres.
Lassen County:				
Lassen Irrigation Co.[1]	1910	5,000	2.07	Mostly alfalfa.
Nevada County:				
Newtown Ditch Co.[1]	1910	85	3.52	Mostly alfalfa.
Sierra Foothills:				
Brown's Valley Canal[1]	1909	1,750	1.74	Clover, 470 acres; alfalfa, 100 acres; fruit, 170 acres; pasture, 800 acres; miscellaneous, 210 acres.
American Canyon Water Co.[2]	1911	4,000	.75	Peaches, grapes, oranges, and olives.
Owens Valley:				
Oak Creek[3]	1909	606	6.83	Alfalfa, 152 acres; barley, 187 acres; corn, 157 acres; pasture, 65 acres; potatoes, 7 acres; vines, 5 acres; other, 33 acres.
Little Shasta Valley:				
Springs	1912	165	7.35	Meadow and pasture.
Sacramento Valley:				
Stony Creek Irrigation Co.[4]	1908	703	3.41	Mostly alfalfa.
Colusa Irrigation Co.[1]	1909	300	3.08	Mostly alfalfa.
San Joaquin Valley:				
Tule River	1901	1,610	2.20	Alfalfa, 255 acres; citrus fruit, 1,054 acres; deciduous fruit, 204 acres, miscellaneous, 97 acres.
San Joaquin and Kings River Canal[2]	1903-1907	74,954	1.55	Diversified crops.
San Joaquin and Kings River Canal[2]	1907-1908	91,051	1.94	Diversified crops.
San Joaquin and Kings River Canal[2]	1911	320	3.21	Grass, 2 farms.
San Joaquin and Kings River Canal[2]	1912	435	2.35	Grass, 3 farms.
Pumping plants, San Joaquin River bottoms	1912	342	.97	Six pumping plants. Alfalfa, 161 acres; deciduous fruits, 150 acres; vines, 31 acres. Diversion estimated.

[1]Data from census, 1910.
[2]Data from company.
[3]Measurements by C. H. Lee.
[4]Data from U. S. Recl. Service.

TABLE 42—Continued.

Summary of miscellaneous data on net duty of water for miscellaneous crops.

Measurements by Irrigation Investigations unless noted otherwise.

Location and source of supply	Year	Acreage	Depth of water applied, feet	Notes
Santa Clara Valley:				
Pumping plants	1904	2,272	1.13	Miscellaneous fields crops and deciduous fruits.
Kirk Ditch Co.	1912	412	1.60	Mostly orchards.
Pajaro Valley:				
Pumping plants	1909	776	3.75	Berries; duty estimated.
Salinas Valley:				
Salinas River and wells	1899			
	1900	1,316	1.32	Sugar beets.
Salinas River	1900	353	1.23	Sugar beets.
Santa Clara River Valley:				
Pumping plants	1912	2,471	.55	Six pumping plants. Walnuts, 893 acres; beans, 752 acres; citrus fruits, 826 acres.
Southern California:				
Pomona Irrigation Co.[2]	1906	2,500	.39	Citrus fruits, 50 per cent; deciduous fruits and diversified.
Pomona Irrigation Co.[2]	1907	2,500	.44	Citrus fruits, 50 per cent; deciduous fruits and diversified.
Pomona Irrigation Co.[2]	1908	2,500	.51	Citrus fruits, 50 per cent; deciduous fruits and diversified.
Pomona Irrigation Co.[2]	1909	2,500	.48	Citrus fruits, 50 per cent; deciduous fruits and diversified.

[2]Data from company.

MISCELLANEOUS DATA REGARDING TIME OF DIVERSIONS.

In connection with recent duty of water and other irrigation studies a considerable amount of information has been collected showing the monthly diversions of canals and the monthly use of water by irrigators. As such information is of value to those planning irrigation systems, whether for a project or a farm, a summary of it is given in the tables following. The data for canals are from representative systems extending from Shasta to Imperial valleys; those for individual farms are from Sacramento Valley only. A number of years should of course be covered to make the data conclusive because use changes from year to year with the wetness or dryness of the seasons.

TABLE 43.

Summary of miscellaneous data on monthly diversions of canals.

Measurements by Irrigation Investigations unless noted otherwise.

Location and canal	Year	Acreage irrigated	Total acre-feet diverted	Per cent of total water diverted each month												Crops irrigated, acres
				January	February	March	April	May	June	July	August	September	October	November	December	
Shasta Valley:[1]																
Terwilliger No. 1	1912	180	291	----	----	----	----	22	31	29	7	11	----	----	----	Alfalfa and meadow.
Terwilliger No. 2	1912	----	2,330	----	----	----	15	14	21	22	15	13	----	----	----	
Soule and Terwilliger	1912	365	2,403	----	----	----	21	20	16	14	13	16	----	----	----	Meadow and pasture.
Company	1912	625	3,079	----	----	----	26	23	17	10	11	13	----	----	----	Meadow and miscellaneous.
Babcock, Soule and Martin	1912	418	2,166	----	----	----	21	33	21	4	5	16	----	----	----	
Hart and Haight	1912	----	435	----	----	----	29	28	17	15	9	2	----	----	----	
Hart and Hoyt	1912	1,665	2,088	----	----	----	19	19	16	16	8	22	----	----	----	Meadow and pasture.
Evans	1912	----	1,118	----	----	----	16	17	16	17	17	17	----	----	----	
Smith	1912	100	636	----	----	----	----	55	38	1	----	6	----	----	----	Meadow.
Haight, Dexter and Kegg	1912	645	2,508	----	----	----	19	20	13	13	17	18	----	----	----	
Kegg	1912	170	964	----	----	----	16	17	16	17	17	17	----	----	----	
Martin	1912	165	1,446	----	----	----	18	18	16	16	16	16	----	----	----	
Dimmick	1912	15	70	----	----	----	----	32	24	19	11	14	----	----	----	
Sacramento Valley:																
Oroville Water Company[2]	1909	880	----	6	6	6	6	12	8	12	12	12	6	6	6	Deciduous and citrus fruits and alfalfa.
South Feather Land and Water Company[2]	1909	1,250	----	----	----	----	16	16	13	13	13	13	11	5	----	Deciduous and citrus fruits and alfalfa.
South Feather Land and Water Company[2]	1912	1,200	6,998	----	----	----	----	11	21	21	16	17	14	----	----	Deciduous and citrus fruits and alfalfa.
Palermo Land and Water Company	1912	1,900	11,506	----	----	----	----	19	23	23	15	10	10	----	----	Deciduous and citrus fruits and alfalfa.
Sutter-Butte Canal Company	1912	14,000	105,382	----	----	----	----	19	17	17	18	16	13	----	----	Deciduous and citrus fruits, alfalfa and rice.
Colusa Irrigation Company[2]	1909	300	924	----	----	----	----	22	23	20	17	17	----	----	----	Alfalfa.
Orland Project[3]	1910	703	4,800	----	----	----	11	50	33	6	----	----	----	----	----	Mostly alfalfa.
Orland Project[3]	1911	2,663	39,211	----	----	----	6	18	17	15	15	13	12	3	1	Alfalfa, citrus and deciduous fruits.
Orland Project[3]	1912	4,230	34,048	----	----	3	11	19	19	17	15	8	8	----	----	Alfalfa, citrus and deciduous fruits.
Orland Project[3]	1913	6,616	40,489	----	[4]---	16	19	22	17	17	9	----	----	----	----	Alfalfa, citrus and deciduous fruits.
East side San Joaquin Valley:																
Modesto[5]	1904	6,895	90,795	12	5	9	10	13	16	16	14	5	----	----	----	
Modesto[5]	1909	22,136	151,600	7	3	6	17	20	20	20	6	1	----	----	----	Alfalfa, 16,306 acres; orchard, 561 acres; vines, 2,404 acres; miscellaneous, 2,865 acres.

TABLE 43—Continued.

Summary of miscellaneous data on monthly diversions of canals.

Measurements by Irrigation Investigations unless noted otherwise.

Location and canal	Year	Acreage irrigated	Total acre-feet diverted	Per cent of total water diverted each month												Crops irrigated, acres
				January	February	March	April	May	June	July	August	September	October	November	December	
Modesto[5]	1912	38,247	152,033	----	4	13	20	27	21	14	1	----	----	----	----	Alfalfa, orchards, vines, grain, garden, beans and corn. Water supply short.
Turlock[5]	1904	20,000	166,845	2	10	4	16	18	6	12	15	7	10	----	----	
Turlock[5]	1909	47,843	231,675	2	3	5	13	20	19	23	8	3	4	----	----	Alfalfa, 27,136 acres; orchard, 5,458 acres; vines, 4,796 acres; miscellaneous, 10,453 acres.
Turlock[5]	1910	64,791	126,139	----	6	16	23	11	8	26	5	5	----	----	----	Alfalfa, 41,845 acres; orchard, 6,143 acres; vines, 4,235 acres; miscellaneous, 12,568 acres.
Turlock[5]	1911	71,106	245,243	----	----	9	16	25	25	25	----	----	----	----	----	Alfalfa, 49,751 acres; orchard, 6,295 acres; vines, 3,802 acres; miscellaneous, 11,258 acres.
Turlock[5]	1912	96,900	253,400	----	4	13	16	24	25	16	2	----	----	----	----	Alfalfa, orchards, vines, potatoes, grain, melons, corn and miscellaneous. Water supply short.
Madera	1912	10,597	28,349	----	----	22	24	26	16	3	3	3	3	----	----	Not given.
Oakdale and South San Joaquin	1912	3,350	35,111	----	----	----	16	19	20	20	20	5	----	----	----	Not given.
Crocker Huffman	1912	28,000	348,767	----	----	14	22	26	22	10	3	2	1	----	----	Not given.
West side San Joaquin Valley:																
Brown Slough[6]	1912	----------	14,114	----	----	----	----	32	65	3	----	----	----	----	----	
Aliso Canal[6]	1912	55,700	35,202	----	----	----	----	38	62	----	----	----	----	----	----	Alfalfa, 13,000 acres; grain, 3,700 acres; pasture and grazing, 39,000 acres.
Chowchilla[6]	1912	----------	87,756	5	3	5	10	22	29	15	7	4	----	----	----	
Helm[6]	1912	----------	116,775	----	----	1	11	22	22	23	11	10	----	----	----	
San Joaquin and Kern River Canal and Irrigation Company main canal[6]	1912	163,350	327,962	5	5	11	15	18	19	17	7	3	----	----	----	
San Joaquin and Kern River Canal and Irrition Company outside canal[6]	1912	----------	108,010	1	4	11	15	18	19	18	10	4	----	----	----	

Eastside[6]	1912	46,560	75,809		3	10	9	37	28	6	4	3				Alfalfa, 2,250 acres; grain, 1,000 acres; pasture and grazing, 38,705 acres; orchard and vines, 190 acres; miscellaneous, 4,355 acres.
Columbia[6]	1912		47,570	4	5	4	10	20	28	13	10	6				
Kern County Canal Company[8]:																
Kern Island[6]	1906		103,718	6	7	5	10	13	12	12	9	8	7	4	7	Alfalfa and miscellaneous.
East Side[6]	1906		35,976	1	2		11	20	12	16	16	9	9	4		Alfalfa and miscellaneous.
East Side[6]	1909	6,000	20,689				11	21	16	19	18	10	5			Alfalfa, grain and miscellaneous.
Farmers[6]	1906		27,500	10	5	4	7	11	10	9	9	6	10	11	8	Alfalfa, grain and miscellaneous.
Farmers[6]	1909	7,000	55,650	8	6	7	11	13	17	12	7	5	9	3	2	Alfalfa, grain and miscellaneous.
Castro	1906		5,895	3	4	3	12	8	10	11	11	12	14	11	1	Alfalfa, grain and miscellaneous.
Stine[6]	1906		23,185	15	10	2	8	20	13	7	9	8	6	1	1	Alfalfa, grain and miscellaneous.
Anderson[6]	1906		18,225	6	3	8	12	14	6	7	12	13	9	8	2	Alfalfa, grain and miscellaneous.
Buena Vista[6]	1906		16,136	9	6	8	10	12	15	13	8	8	6	4	1	Alfalfa, grain and miscellaneous.
James[6]	1906		34,528	4	2	14	6	9	11	12	9	10	8	8	7	Alfalfa, grain and miscellaneous.
Wilson[6]	1906		7,557	3	5	12	10	21	22	21	5					Alfalfa, grain and miscellaneous.
Beardsley[6]	1906		42,521	4		6	13	14	18	13	21	8	3			Alfalfa, grain and miscellaneous.
Lerdo[6]	1906		12,780			18	6	27	22	18	6	3				Alfalfa, grain and miscellaneous.
Calloway[6]	1906		210,261	1		6	22	23	17	16	7	4	3	1		Alfalfa, grain and miscellaneous.
Pioneer[6]	1906		59,932	9	5	5	13	13	19	9	7	5	8	4	3	Alfalfa, grain and miscellaneous.
Wasco:																
Fourth Extension[6]		1,940	5,000				25	15	15	15	15	15				Alfalfa, grain and miscellaneous.
Santa Clara River Valley, Ventura County:																
Camulos	1912	400	1,707					11	27	22	16	15	9			Alfalfa, 150 acres; citrus fruits, 60 acres; deciduous fruits, 190 acres.
Hardgrave & Comfort	1912	470	2,583					18	26	17	9	9	21			Alfalfa, 115 acres; citrus fruits, 5 acres; miscellaneous, 350 acres.
Piru Water Company	1912	376	1,419					9	19	22	21	21	8			Citrus fruits, 216 acres; deciduous fruits, 160 acres.
South Side Improvement Company[9]	1912	1,400	1,061					13	20	22	18	15	12			Citrus fruits, 700 acres; deciduous fruits, 700 acres.
Stringtown & Carmicle	1912	350	2,054					4	13	27	20	19	17			Alfalfa, 350 acres.
Fillmore Irrigation Company	1912	1,674	3,328					13	25	20	14	14	14			Alfalfa, 58 acres; citrus fruits, 1,497 acres; deciduous fruits, 119 acres.
Interurban Land and Water Company	1912	1,112	1,487					19	19	20	20	14	8			Alfalfa, 350 acres; citrus fruits, 354 acres; deciduous fruits, 380 acres; miscellaneous, 28 acres.
Santa Clara Water and Irrigation Company	1912	1,734	4,699				1	20	14	21	18	17	9			Alfalfa, 40 acres; citrus fruits, 348 acres; miscellaneous, 1,346 acres.
River Street	1912	1,536	3,540					19	23	13	21	21	3			Alfalfa, 200 acres; deciduous fruits, 1,266 acres; miscellaneous, 70 acres.
Saticoy	1912	4,414	6,282					2	25	36	17	13	7			Alfalfa, 173 acres; citrus fruits, 155 acres; deciduous fruits, 374 acres; miscellaneous, 3,712 acres.

TABLE 43—Continued.

Summary of miscellaneous data on monthly diversions of canals.

Measurements by Irrigation Investigations unless noted otherwise.

Location and canal	Year	Acreage irrigated	Total acre-feet diverted	Per cent of total water diverted each month												Crops irrigated, acres
				January	February	March	April	May	June	July	August	September	October	November	December	
Santa Paula Water Works	1912	1,628	1,772	----	----	----	11	19	20	16	13	11	10	----	----	Citrus fruits, 748 acres; deciduous fruits, 880 acres.
Turner[10]	1912	187	1,492	----	----	----	----	10	26	26	18	14	6	----	----	Alfalfa, 12 acres; citrus fruits, 74 acres; deciduous fruits, 62 acres; miscellaneous, 39 acres.
Sespe Land and Water Company	1912	40	603	----	----	----	----	----	16	47	16	12	9	----	----	Alfalfa, 40 acres.
Santa Ana Valley:																
Bear Valley Mutual Water Company[6]	1912	15,000	30,070	7	5	----	7	10	13	14	13	12	12	7	----	Citrus fruits, 15,000 acres.
Fontana Development Company[6]	1912	15,000	19,607	7	8	13	8	13	11	9	7	6	6	6	6	Alfalfa, 800 acres; citrus fruits, 12,800 acres; miscellaneous, 1,400 acres.
Riverside Water Company[6]	1912	9,000	26,170	10	6	----	10	12	13	13	12	12	12	----	----	Alfalfa, 3,900 acres; citrus fruits, 4,500 acres, miscellaneous, 600 acres.
Santa Ana Valley Irrigation Company[6]	1912	17,000	32,583	10	15	16	16	11	7	5	4	4	4	4	4	Citrus fruits, 12,200 acres; deciduous fruits, 5,400 acres; miscellaneous, 1,365 acres.
Anaheim Union Water Company[6]	1912	13,000	26,890	13	12	13	12	12	7	6	5	5	5	5	5	Citrus fruits, 11,270 acres; deciduous fruits, 3,875 acres; miscellaneous, 3,100 acres.
City Creek Water Company[6]	1912	320	678	----	----	----	----	36	29	17	10	8	----	----	----	
Imperial Valley:																
Imperial Water Company No. 1[11]	1905	----------	105,669	5	2	6	18	10	10	12	11	8	7	5	6	
Imperial Water Company No. 1[11]	1906	70,000	126,859	9	5	14	13	9	9	8	8	7	7	6	5	
Imperial Water Company No. 1[11]	1909	----------	214,333	6	8	9	11	10	11	11	8	7	7	6	6	
Imperial Water Company No. 1[11]	1910	90,911	236,361	5	6	11	11	11	11	8	8	9	8	6	6	Alfalfa, 43,503 acres; grain, 27,004 acres; vines, 1,569 acres; miscellaneous, 18,835 acres.
Imperial Water Company No. 1[11]	1911	99,572	274,665	4	4	8	9	10	11	11	12	11	8	6	6	Alfalfa, 44,267 acres; grain, 28,897 acres; vines, 1,352 acres; miscellaneous, 25,061 acres.
Imperial Water Company No. 1[11]	1912	100,681	318,122	6	6	9	9	9	11	11	11	9	8	6	5	Alfalfa, 47,116 acres; grain, 26,241 acres; vines, 926 acres; miscellaneous, 26,398 acres.

Imperial Water Company No. 1[11]	1913	100,681	337,349	4	5	8	9	11	12	13	12	9	8	5	4	acres; vines, 910 acres; miscellaneous, Alfalfa, 59,279 acres; grain, 19,257 21,235 acres.
Imperial Water Company No. 4[11]	1905	----------	22,700	6	1	4	18	9	7	15	8	6	5	6	15	
Imperial Water Company No. 4[11]	1906	15,000	24,307	11	4	19	18	8	6	5	4	4	6	8	7	
Imperial Water Company No. 4[11]	1913	17,500	59,201	6	5	10	9	10	12	11	11	8	6	6	6	Cantaloupes, alfalfa, barley, corn, vegetables, fruits and miscellaneous.
Imperial Water Company No. 5[11]	1905	----------	35,571	10	7	1	17	8	5	9	9	8	10	5	11	
Imperial Water Company No. 5[11]	1906	25,000	65,278	8	4	14	13	9	12	10	9	7	6	5	3	
Imperial Water Company No. 5[11]	1913	47,025	197,637	4	5	9	10	11	10	12	12	9	8	5	5	Alfalfa, barley, corn, cotton, and miscellaneous.
Imperial Water Company No. 6[11]	1913	17,600	51,854	4	4	8	12	11	11	12	13	10	8	4	3	Barley, cotton, corn, alfalfa and miscellaneous.
Imperial Water Company No. 7[6]	1905	----------	17,592	10	5	1	23	10	4	1	13	13	8	4	8	
Imperial Water Company No. 7[11]	1906	10,000	21,278	7	5	12	12	10	9	9	7	9	7	6	7	
Imperial Water Company No. 7[11]	1913	16,000	61,181	4	4	8	8	11	12	14	13	10	8	4	4	Alfalfa, 75 per cent; remainder diversified.
Imperial Water Company No. 8[6]	1913	24,000	89,809	5	6	10	10	10	10	10	12	10	7	5	5	Alfalfa, 50 per cent; melons, cotton, corn, barley and grapes.
Imperial Water Company No. 12[6]	1913	12,000	30,152	4	5	8	12	13	9	11	14	10	7	4	3	Cotton, 50 per cent; alfalfa, barley and corn.
Mutual Water Company[11]	1904	----------	302,708	7	6	8	8	9	7	9	9	8	9	11	9	
Imperial South Side Water Company[11]	1913	16,000	44,708	4	5	8	9	10	11	15	13	9	6	5	5	Alfalfa, 50 per cent; corn, cotton, barley and miscellaneous.

[1]In some cases Shasta Valley ditches reported diverted small quantities of water in both March and October.
[2]Data from irrigation census 1910.
[3]Data from U. S. Reclamation Service.
[4]A negligible quantity diverted in February.
[5]Data from district.
[6]Data from company.
[7]Included in main canal, San Joaquin and Kern River Canal and Irrigation Company.
[8]Diversions for some ditches estimated for September and for all ditches for October.
[9]Company record.
[10]Only about 4 acre-feet used, the balance returned to the river.
[11]Data from company or companies.

TABLE 44.

Summary for sixty-two Sacramento Valley farms showing percentage of seasonal application of irrigation water used during each month of the irrigation season.

Section and tract	Year	Acreage	Total acre-feet applied	Per cent of total water applied each month											
				Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Gridley:															
J. W. Humble	1913	18 43	47 00					32	28	19	21				
T. Baltimore	1913	14 93	51 06					31	22	25	22				
F. L. Bratton	1913	3 29	12 57					23	25	28	24				
Chas. Baltimore	1913	26 40	131 47					28	19	19	17	17			
W. R. Huartson	1913	7 42	34 43					32	23	23	22				
C. W. Van Note	1913	27 20	64 46					27	21	17	11	24			
W. G. Coppernoll	1913	13 96	39 51					22	19	23	10	26			
M. B. Williams	1913	67 29	137 27					28	25	18	29				
A. J. McFarland	1913	9 44	39 27					29	22	17	15	17			
Jno. Paulhorn	1913	17 10	67 20					30	24	23	23				
C. W. Summers	1913	7 00	15 61					37	18	21	24				
G. W. Conrad	1913	37 59	143 22					23	18	18	15	26			
G. L. Campbell	1913	16 76	65 20					28	15	20	13	24			
C. N. Mount	1913	17 41	64 42					28	13	12	12	35			
Los Molinos:															
E. A. Bundy, north field	1913	8 97	44 04						12	28	32	28			
E. A. Bundy, north field	1914	8 97	21 37					31	22	24	23				
E. A. Bundy, south field	1913	4 31	26 12					27	22	27		24			
E. A. Bundy, south field	1914	4 31	17 70					36	25	23	16				
R. W. Ballard	1913	10 18	61 18						25	34	28	13			
O. W. Chambers	1914	4 52	6 45					19	12	20	38	11			
G. B. Engle	1913	17 15	76 49					17	22	29	16	16			
G. B. Engle	1914	23 35	64 73					30	11	14	20	25			
G. H. Geer	1913	9 21	68 25						20	26	28	26			
G. H. Geer	1914	4 40	28 86					31	23		15	31			
J. F. Hofhenke	1913	24 59	92 95						31	27	22	20			
J. F. Hofhenke, north field	1914	13 27	112 38					25		26	24	25			
J. F. Hofhenke, south field	1914	11 32	62 85					28		24	28	20			
R. F. Massie, north field	1914	8 92	45 07					6	20	23	15	13	23		
R. F. Massie, south field	1914	4 84	17 64					36	16	22	12	14			
S. B. Reece	1913	13 50	82 22					17	35	25		23			
S. B. Reece	1914	13 50	73 94					35	9	22		34			

John Risse	1913	15 00	95 70							21	31	25	23					
A. Wigno	1913	9 13	46 38						19	20	37	24						
A. Wigno	1914	6 70	40 75						8	32	22		38					
H. N. Woodward	1914	9 08	35 84						25	26	22	27						
Orland:																		
David Brown	1913	76 45	361 61			24	14	18	14	14	12	18						
David Brown	1914	76 45	385 31					22	14	14	26	13	25					
R. F. Brantley	1914	7 75	31 23				10	11	14	14	21	19	18	7				
C. E. Fellerson	1913	32 45	91 83				11	34	22	18	15							
C. E. Fellerson	1914	14 79	38 31					34	27	20	10	9						
H. M. Lawton	1913	18 61	79 84			8	11	22	14	39	6							
H. M. Lawton	1914	18 61	178 47				8	24	16	14	15	23						
E. F. Nickolls	1914	16 66	54 14					21	25	21	9	13	11					
J. E. Holland	1914	37 00	279 72			8	8	8	15	15	14	24	8					
Roy O'Hair	1913	34 20	108 07			35		23	16	16	10							
Roy O'Hair	1914	34 20	35 57					50	24		26							
A. C. Spence	1913	8 06	31 49			9	9	21	21	20	20							
A. C. Spence	1914	27 70	154 01					20	18	19	21	11	11					
Willows:																		
P. S. Cook	1914	15 65	26 28					13	23	20	22	22						
C. F. Goos	1914	13 00	23 79					11	19	18	31	21						
L. E. Tuttle	1914	35 06	44 88					23	27	30	20							
V. E. Breeze	1914	35 95	64 35					20	14	14	20	32						
Jas. Purdy	1914	11 37	19 21					35	22		43							
W. B. Pine[1]	1914	3 34	6 58					13	26	15	31	15						
Woodland:																		
Geo. W. Hughson	1913	19 54	86 05			19		50	31									
Geo. W. Hughson	1914	19 54	56 84						4	71	25							
H. J. N. Rasmussen	1913	15 94	67 31			39		34	27									
Sylvester Lawson	1913	25 63	61 08			42		21		25		12						
Wm. Exley[2]	1913	23 20	65 15			30		26		25		19						
John Beck[2]	1914	23 20	36 80							61		39						
R. E. Fisher[1]	1913	37 71	49 10							61	20	11	8					
R. E. Fisher, west plat[1]	1914	21 50	43 58						51		24	25						
Frank Hermle	1913	23 88	74 52			40		32		28								
Geo. O. Griffes, south field	1913	16 65	51 18			26		24		21		29						
Geo. O. Griffes, south field, east plat	1914	5 48	7 74							100								
Geo. O. Griffes, south field, west plat	1914	11 17	11 20							100								
Geo. O. Griffes, north field	1913	48 80	158 93					38		28		34						
Geo. O. Griffes, north field	1914	48 80	95 73						51		49							
D. B. Guile	1913	28 21	60 50			23		28	24			25						
D. B. Guile	1914	28 21	32 19						53	42	5							
Jackson & Woodard, north plat[1]	1913	10 26	34 72			24		18	14	15	13		16					

TABLE 44—Continued.

Summary for sixty-two Sacramento Valley farms showing percentage of seasonal application of irrigation water used during each month of the irrigation season.

Section and tract	Year	Acreage	Total acre-feet applied	Per cent of total water applied each month											
				Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jackson & Woodard, north plat[1]	1914	10 26	21 92						47	29		24			
Jackson & Woodard, south plat[1]	1913	9 49	29 18			25		19	15	15	13		13		
Jackson & Woodard, south plat[1]	1914	9 49	17 83						42	31		27			
Mrs. Nettie Hadsall	1913	35 76	75 40			44		56							
Dixon:															
J. R. Bloom	1913	10 36	29 22					18	15	17	17	19	14		
Mrs. Letitia Cooper	1913	10 01	22 74				26	24	26	17		7			
C. E. Schmeiser	1913	36 20	110 79			11	7	11	14	23	18	16			
D. W. Wright	1913	12 10	38 07				13	13	11	30	13	7	13		
M. D. Campbell	1913	36 74	102 48			6	8	8	20	16	20	14	8		
E. D. Dudley	1913	26 64	78 01			6	6	18	13	19	9	27	2		
Harry McFayden	1913	74 12	254 37			6	13	8	13	18	18	14	10		

[1]Pumping plant.

[2]Exley and Beck tracts identical.

PUBLICATIONS.

The following publications giving results of irrigation investigations in California have been issued during the past two years:

Irrigation Resources of Northern California. By Frank Adams. Printed in Report of State Conservation Commission, 1912.

Irrigation Resources of Central California. By S. T. Harding and Ralph D. Robertson. Printed in Report of State Conservation Commission, 1912.

Irrigation Resources of Southern California. By C. E. Tait. Printed in Report of State Conservation Commission, 1912.

Irrigation Resources of California and Their Utilization. By Frank Adams. Office of Experiment Stations, Bulletin 254, U. S. Dept. Agr.

Progress Report of Cooperative Irrigation Experiments at California University Farm, Davis, Cal., 1909–1912. By S. H. Beckett. Bul. 10, U. S. Dept. Agr.

Some Measuring Devices Used in the Delivery of Irrigation Water. By California Agents of Irrigation Investigations. Bul. 247, University of California Agricultural Experiment Station.

In addition to the above, a bulletin on irrigation and soil conditions in the Sierra Nevada foothills, by R. D. Robertson, Irrigation Engineer, Office of Experiment Stations, and J. W. Nelson, Assistant Professor of Soil Technology, University of California, is now ready for printing by the College of Agriculture of the University of California.

PRESENT STATUS OF IRRIGATION IN CALIFORNIA.

After sharing in the over expansion in irrigation development which occurred throughout the West following the passage by Congress of the Reclamation Act of June 17, 1902, California during the past two years has in the main settled down to a process of readjustment and of waiting for settlement to catch up with irrigation construction. While no complete figures of increases are available for any part of the state, it is quite certain that outside of a few localities the additions to the irrigated acreage during the past two years have been below the normal of the preceding decade. The increase in the irrigated acreage in California from 1899 to 1909 was at the rate of about 122,000 acres per year, making the total area irrigated in 1909, 2,644,104 acres. Our studies of irrigation resources in 1912 showed a total area irrigated that year of 3,192,646 acres, indicating that the rate of increase from 1909 to 1912 was above the preceding ten-year normal.

The increase since 1912 in the irrigated area in northern California has not been large, nor have any very extensive additional areas been brought under ditch during the past two years in that part of the state. The main construction improvements during the period have been on Cache and Stony creeks. On Cache Creek dams have been completed at Capay and at the outlet of Clear Lake near Lower Lake. Besides this, Adams Canal has been lined with concrete for a distance of two miles beginning at Capay dam. Winters Canal, on the opposite side of the creek, has been lined for a distance of 5 miles to the intake of Madison Canal. The Moore section of the Yolo system has been lined for a distance of about 3 miles, beginning about one mile below Moore Dam. Activities on Stony Creek have been confined to the Orland project of the Reclamation Service. Improvements on this project have mainly consisted in the building of a supply canal 6½ miles long to carry the drainage of Stony Creek to East Park Reservoir, which is located on Little Stony Creek. This additional water supply has made it possible to increase the area of this project from 14,000 to 20,000 acres, the distribution system for which, with concrete structures, is now in course of construction. New construction on the east side of Sacramento Valley has mainly consisted of additional laterals of Sutter-Butte Canal to reach the rice lands about Biggs and Gridley. Other forward movements in northern California irrigation development since 1912 have included a reorganization of the main Susan River sys-

tem, the development of a number of wells around Big Spring in Shasta Valley, an increase in the water available for irrigation in the Placer County foothills, and the cooperative studies of Iron Canyon project and of the possibilities of Pit River irrigation development now being made under agreement betweeen the Reclamation Service and the State Department of Engineering. In matters of irrigation institutions the most important movements have been in connection with proposed irrigation districts at Oroville, Chico, and Fair Oaks, and in the organization of the Anderson-Cottonwood district near Anderson.

There have been no large additions in central California during the biennium but some progress has been made all along the line. The largest areas brought under ditch have been in South San Joaquin and Oakdale irrigation districts, both of which began delivering water through the new works in 1914. Both Modesto and Turlock irrigation districts continued permanent improvements on the upper works and Turlock District has constructed the Davis foothill reservoir. An irrigation district has been organized at Waterford, but no plans for a system have been adopted and no construction begun. The chief interest around Merced and Madera has been the proposed organization of districts to take over the local system there. On the west side there has been much interest in irrigation from Tracy north, following the two dry years of 1912 and 1913. For a time there was much talk of an irrigation project for Tracy, Bethany, and Byron, but the only definite accomplishment has been the organization of a cooperative company at Byron which proposes to build a pumping system for several thousand acres immediately about that place. The need for irrigation in the orchard section about Oakley has come to be quite generally recognized in the past two years, and this office has assisted toward the making of definite plans there through a preliminary study and report on a proposed pumping system. The Brentwood pumping system, covering about 10,000 acres, has been completed during 1914, although little if any new settlement has occurred there under the project. In the portion of San Joaquin Valley about Fresno there has been much discussion of the coordination of all of the sections, looking to the better control of irrigation and flood waters; and about both Fresno and Bakersfield the idea is gradually developing that the systems there should be taken over by irrigation districts or other farmers' organizations.

In southern California the largest increases since 1912 have been in Imperial Valley. An extension of the canal system of Imperial Water Company No. 5 and the construction of a system by Imperial Water Company No. 3 are in process of adding 100,000 acres to the area under ditch there. The system of the Palo Verde Mutual Water Company has also been increased until it is now constructed to cover about 45,000 acres. Outside of these increases the main interest in the Colorado River sections has been in the completion of the organization of Imperial Irrigation District and the proposed formation of an irrigation district for Chuckawalla mesa. The recent overwhelming majority in favor of a bond issue of $3,500,000 in Imperial Valley with which to purchase the system of the California Development Company seems permanently to establish Imperial Irrigation District in the minds of the valley people and the next two years should see a decided advance in the water situation there. Although the legislature of 1913 passed a special irrigation law at the instance of those furthering development on Chuchawalla mesa, an effective organization there has not yet been worked out. Completion of the Los Angeles aqueduct has brought nearer a solution of the problem of utilizing surplus waters of the aqueduct for the irrigation of lands in San Fernando Valley, and, as pointed out elsewhere in this report, several San Fernando communities are in process of organization into irrigation districts under the law enacted by the last legislature at the instance of the Los Angeles authorities. Outside of these lines of irrigation development southern California irrigation advances during the past two years have been mainly through pumping, as detailed in the paragraph by Mr. Tait on irrigation development in southern California. A new irrigation district under the Bridgeford act has been formed

about La Mesa, known as the La Mesa, Lemon Grove and Spring Valley Irrigation District, and substantial improvements have been made in the small system of the San Ysidro Irrigation District at San Ysidro. Mr. Tait estimates the total increase in the irrigated area in southern California since 1912 as between 50,000 and 60,000 acres.

As detailed elsewhere in this report, there has been a very substantial increase in the number of irrigation pumping plants in California since January 1, 1911. The best data available indicate that the total number of such plants in the state now approaches 25,000, as against less than 10,000 when the irrigation census of 1910 was taken. This large increase is certainly significant of the growing importance underground waters are having in California irrigation.

It has come to be well recognized that the problems of western irrigation are no longer problems of construction, but rather of settlement and operation. In most of the western states the settlement of lands brought under ditch is looked upon as the largest institutional problem connected with agriculture, as it probably is in California also at this time. In the past season considerable thought has been devoted by this office to the question of the settlement of irrigation projects. Data have been gathered from settlers on several projects in Sacramento Valley, and in cooperation with the College of Agriculture of the University of California a study has been made of the operation of the land settlement policy of the Canadian Pacific Railway in western Canada. We are further cooperating with the University in connection with a committee on rural credits and land settlement appointed by the President of the University to draft measures to be submitted to the coming legislature. The present methods of haphazard settlement of irrigated lands have raised the price of land to settlers to a nearly prohibitive figure. This, together with other tendencies prevailing in agriculture development which are increasing costs to the farmers, has practically placed the successful development of a 40-acre irrigated farm out of reach of the settler having less than $5,000 at his command. This is the testimony of investors as well as of settlers themselves. On most California projects settlers have been led to purchase land with only sufficient money to make initial payments and provide minor equipment and improvements. In many cases the result of this condition has been the abandonment of the land contracted for. In other words, the optimistic statements of land selling agencies have led men ill equipped, both financially and by training and temperament, to undertake to establish homes on irrigated farms. While some of those who have settled will succeed and some will fail, it seems quite certain that California will not receive her share of the right kind of settlers on irrigated farms unless present conditions are radically changed. The belief that this is the case has led many to conclude that the time is ripe for the state itself to establish a land settlement policy under which it shall do for the settlers some of the things that are being successfully done for settlers in Australia and Canada. In both Australia and Canada settlers are furnished lands at a very much lower price per acre than the price of irrigated lands in California. While the usual terms of payment in California are ten years, in Canada the Canadian Pacific Railway allows twenty years; and in Victoria, Australia, land is sold on an amortization plan under which annual payments of 6 per cent on the purchase price of the land take care of interest and extinguish the principal in 31½ years. In both Canada and Australia the settler is given even additional aid in the way of "ready made" improvements or loans for improvements, as well, in some cases, as loans for purchasing stock.

Along with the question of greater aid to settlers on California irrigation projects, the economical use of irrigation water is coming to overshadow other irrigation problems in the state. Our studies of irrigation resources have indicated, as conclusively as it is possible to do without detailed engineering examinations covering the entire state, that there is sufficient irrigation water in California for less than one half of the area which needs water or that would be greatly benefited by it. Even the irri-

gation of the 9,000,000 acres which it is estimated may ultimately be watered can be brought about only by the establishment of more economical standards of use than now prevail in many parts of the state. It is believed the work of the new State Water Commission will be of tremendous force in establishing a more economical irrigation practice, especially in northern and central California, and it is largely because of this belief that much of the effort of this office is now being devoted to studies of economical duty.

Outside of the final adoption of the Water Commission Act, along the lines of which this Office has been interested since the beginning of its work in this state fifteen years ago, the most striking changes in the water laws of the State of California during the past two years have been those affecting irrigation districts. The addition of three complete irrigation district laws to the irrigation district statutes of the state, which was accomplished by the legislature of 1913, has brought problems of irrigation district organization that are entirely new. While the Bridgeford act with its amendments is coming to be thoroughly understood and its main features interpreted by the Supreme Court, the new laws, which do not have the restrictions that have been gradually built around the Bridgeford act, have increased many fold the opportunities for mistakes and therefore the responsibility of public agencies to aid in guarding against the misuse of these laws. A tendency has already appeared to substitute some of the later district legislation for the Bridgeford act when forming new districts. Until more is known about the new laws it is believed that our influence can well be exerted in favor of utilizing the irrigation district law that is already established when new districts are formed, at least, outside of the particular zones for which the new legislation was specially designed.

APPENDIX TO REPORT OF COOPERATIVE IRRIGATION INVESTIGATIONS.

Investigation of Wells in Imperial Valley.

Introduction by C. E. Tait, Irrigation Engineer, Office of Experiment Stations, U. S. Department of Agriculture.

An examination of the wells of Imperial Valley and the adjacent desert was made in the winter of 1913–14 by Wells A. Hutchins. The geology of this section is discussed in Water Supply Paper 225 of the U. S. Geological Survey, entitled "Ground Waters of the Indio Region, California, with a Sketch of the Colorado Desert," while the use of water and its results is discussed in Document 246, U. S. Senate, sixtieth Congress, first session, entitled, "Irrigation in Imperial Valley—Its Problems and Possibilities."

Since these reports were issued, numerous flowing wells have been secured on the east side of Imperial Valley. Simultaneous with this development there has been much inquiry relative to the source and extent of the underground water and the possibility of securing stronger flowing wells by drilling to greater depths. The discovery of artesian water also revived interest in the possibility of irrigating land on the west side of Imperial Valley and in San Felipe Valley from wells. Neither the desert lands to the west nor the mesa to the east are within the territory to which the California Development Company expects to deliver water from Colorado River, nor are they in the newly organized Imperial Irrigation District which proposes to acquire the irrigation system of the Development Company. The east mesa may be irrigated by gravity from Laguna Dam.

Very little was known of the underground waters of the southeastern portion of Colorado desert prior to the construction of Imperial Canal in 1900. Coachella Valley, on the other side of Salton Sink, at the northwest end of the desert, then had a large number of flowing wells, but these were fed by drainage from the mountains to the northwest. The first bore in Imperial Valley, made at Imperial in 1905 to a depth of nearly 800 feet, was dry at the bottom. The next attempt was by the

city of Holtville, which in 1909 secured a flow of 48 gallons per minute on the townsite from strata at 836 and 1104 feet in depth. From this beginning the number of flowing wells on the east side increased rapidly until by the end of the past winter 33 had been drilled between Alamo River and the east-side mesa, all of which flow. One, the Rose School well, west of the Alamo River, flowed for one year after its completion. The area in which artesian water can be secured at reasonable depth has been fairly well determined. Other bores of much significance were at El Centro and Brawley in 1910. The El Centro well was 1,015 and the Brawley well 2,032 feet deep. Neither reached water.

The east-side wells are not productive enough for irrigation, but are useful for domestic purposes and for live stock. The water from many of the wells is too salty to be used for irrigation, although the town of Holtville mixes the water with ditch water without disastrous results to plants. The water is not pleasing to taste and it is too warm when first discharged to be refreshing, but it is healthful and of great value to the section of country where it is available.

The old beach line is the eastern limit of the artesian area. Only one flowing well, that of the Alamo School, is situated above sea level. The elevations range from 9 feet above sea level at the Alamo School to 137 feet below sea level at the Alamario well. These two wells mark the extreme southeastern and northwestern limits of the artesian area. The Storey, one of the most eastern wells, is 5 feet below sea level, while the Rose School well, the farthest to the west, is 90 feet below sea level.

Eliminating the Boyd well, which is of small diameter, the water pressure at the surface of the ground ranges from 1.65 pounds per square inch at Thompson's well near Holtville, to 31.67 pounds per square inch at the Ferguson well. The pressure does not depend on the elevation, as most of the wells toward the north which are the farthest below sea level indicate light pressure.

The discharge, not considering the Boyd well, varies from .19 gallon per minute at the Phegley to 83.7 gallons per minute at the Hazzard and Strang well. Among the other better flowing wells are the Ferguson, Rohrer, Holtville City, Hooker and Bell, and T. Prim wells. The location of these is in a belt stretching 4 miles north from Holtville. An exception to the rule is the strong flow of the Alamario well at the extreme northwest.

In general the wells with the strongest pressure give the highest discharge, but there is no direct relation between the two. Pressure depends on the head to which the water is subject and it corresponds to the elevation at which the water would stand when quiet. The flow depends on this and, in an inverse manner, on the resistance offered the water at its entrance to the well casing and in its approach to the well through the sands and gravels from which it is derived. The comparatively high flow of the Hazzard and Strang well is no doubt due to the screen in the well casing at the water-bearing strata, which gives a large area of opening into the well and prevents the entrance of sands into the casing. The lighter flowing wells are fairly well distributed over the area.

The temperature of the discharging water ranges from 72 to 117 degrees Fahrenheit, the lowest being at the Cox well and the highest at the J. Prim well. In general, the temperature decreases toward the northwest.

It is probable that the main source of the water is Colorado River. This is indicated by a consideration of the pressure and elevations of the wells, the location of the artesian area, and the temperature of the water. The wells are about 100 feet below the level of Colorado River, directly to the east. The watershed and the precipitation on the mountains, sandhills, and mesa to the northeast are hardly sufficient to produce the results secured. The water from the wells in Coachella Valley, having its source in the larger and more valuable drainage areas of the San Bernardino and San Jacinto mountains, generally has a temperature of about 80 degrees, although it increases slightly toward the south. Again, the quality of the

water is much different from that of Coachella Valley wells. It is probable that the ground waters are divided at Salton Sea or that the seepage toward Salton Sea from both directions finds an outlet into this sink or lake, where it evaporates into the atmosphere or augments the waters of the lake.

The lack of success in drilling in the central portion of the valley and in Imperial, El Centro, and Brawley, is discouraging, yet it is possible that flowing water might be secured by boring to still greater depths. The wells along the railroad in Mexico may be fed from seepage from Colorado and Alamo rivers and the various sloughs which cross this section of the desert.

There is yet much speculation relative to the possibility of securing either flowing wells or wells that may be pumped for irrigation on the west side of Imperial Valley. The wells located on the plain south of Superstition Mountain reach water of rather poor quality. It is possible that good water might be secured in a limited amount at certain localities near the foothills on the west side. The mountains and hills to the west, although barren, should produce some drainage which is taken up by the gravels at their base.

San Felipe Valley, at the junction of Carrizo Creek, contains a large area of fine land, the soil being similar to that of Imperial Valley. This section is below sea level. The watershed contributing to this part of the desert is not of sufficient value to furnish water for irrigation of more than a comparatively small portion of the good land. Harper's well produces a small flow of water of fair quality from a 300-foot stratum. Some of the other wells in this section have reached water unfit for irrigation or domestic use at less depth. An examination of the record of the borings indicates that wells should not be undertaken unless preparations have been made to drill to a considerable depth. The upper strata are no doubt fed in part from rains on the desert, the water carrying the salts down in solution. The lower strata should be fed from the more distant debris cones at the mouths of the small mountain streams. The boring of deep wells in such an inaccessible locality is expensive. The only safe method would be for the development to proceed gradually by small units. In this way the limit of the water supply need not be exceeded.

The underground waters at great depth in Imperial Valley apparently have no connection with the so-called surface or subsoil waters found, in some localities, in strata from 20 to 50 feet beneath the surface.

REPORT ON INVESTIGATION OF WELLS IN IMPERIAL VALLEY, 1914.

By Wells A. Hutchins.

During the winter of 1913–1914 an investigation was made of all the wells in Imperial Valley, with a view to ascertaining the limits of the artesian area and the possibilities of further development of underground waters. Data were collected relative to the actual depths of the wells, the distance to water if not flowing, character of the strata of soil penetrated, etc., and tests of the pressure, discharge, and temperature of the artesian wells were made wherever feasible.

The discharge of the wells was measured in most cases by noting with stop watch the time required to fill a five-gallon oil can. This method was found convenient and sufficiently accurate for practical purposes with wells of such small flow. The water pressure was ascertained by a standard test gauge, and the temperature of the water was taken by a carefully calibrated thermometer. The depths, location of artesian strata, and logs of the wells were ascertained from the drillers or their assistants in all cases except where otherwise noted. The elevations were secured from records of the California Development Company.

For convenience in studying the subject, Imperial Valley has been divided into seven districts and the data on all of the wells in each district grouped under one heading. (See map attached.)

Area No. 1.

This area comprises the territory lying between the ancient beach line on the east side of the valley and an arbitrary line running approximately halfway between Alamo River and the Southern Pacific Railroad from the international boundary line north. This area contains, with one exception, all of the flowing wells in the valley at the present time. The single exception is Harper's well, northwest of Superstition Mountain. The western line of this area seems to mark the western limit of artesian water that can be obtained at a reasonable depth, for wells have been drilled at several towns along the railroad much deeper than any in this area without developing flowing water.

As the fall of the surface is from the east and south, and as the western portions of the valley may be considered as nonartesian, it would seem to follow that the flowing water found in Area No. 1 originates east of the old beach line. There are no mountains to the east or northeast, however, from which the run-off is sufficient to feed the strata underlying this area; hence the conclusion seems warranted that they are fed by the waters of Colorado River.

Following are data on the individual wells of the area and a tabular summary of their salient features:

City of Holtville.—Located in section 36, T. 15 S., R. 15 E., completed in 1909, by Coachella Valley Development Company. The discharge and temperature were measured March 5, 1914, but it was not feasible to measure the pressure.

Log:

Material	Depth to which extends, feet
Soil	50
Clay	113
Fine sand	132
Clay	176
Coarse sand, carrying water	180
Fine sand	205
Clay	255
Fine sand	267
Clay	280
Fine sand	296
Clay, very hard	490
Fine sand	508
Clay	836
Gravel, where casing landed	848
Clay	1,100
Gravel, not tested, but appeared good	1,120
Clay	1,340
Sand cement, quite hard	1,350
Clay	1,410

Water analysis, furnished by city of Holtville.

	Grains per gallon
Magnesium carbonate	42.98
Magnesium sulphate	.31
Calcium chloride	.00
Magnesium chloride	.00
Calcium hydroxide	.00
Silica and oxides of iron and al.	2.51
Alkali carbonates	.70
Alkali sulphates	.35
Alkali nitrates	.00
Alkali chlorides	20.52
Organic matter	2.75

This water was found to be too salty for irrigation at Holtville unless mixed with ditch water.

This is one of three wells which are connected and of which the combined flow passes into a reservoir where it is mixed with ditch water. It is then pumped into a tank and distributed to the city for domestic purposes. On March 2, 1914, the combined discharge of the three wells was 57.7 gallons per minute. The temperature of the combined waters was 109° and of the air 73°.

City of Holtville.—Located in section 36, T. 15 S., R. 15 E. Drilled by Coachella Valley Development Company. The pressure, discharge, and temperature were measured March 5, 1914.

City of Holtville.—Located in section 36, T. 15 S., R. 15 E. Drilled by J. D. McNeil. A Layne and Bowler starter and no screen was used. The flow and temperature were measured March 5, 1914, but it was not feasible to measure the pressure.

City of Holtville—Located in section 36, T. 15 S., R. 15 E. Drilled in 1911 by J. D. McNeil. Has 6-inch screwed casing. No flowing water was obtained, for the tools were stuck at a depth of 775 feet. A slight amount of water-bearing sand was found at a depth of 42 feet, with another stratum between 375 and 396 feet in depth. The elevation of the surface is –15 feet. This was located close to the natatorium well.

Holtville Natatorium.—Located in section 36, T. 15 S., R. 15 E. Drilled by Coachella Valley Development Company. Has 4-inch (outside diameter) screwed casing, but it reduced to 2 inches (inside diameter) and carried horizontally to a swimming tank. There one pipe descends to the floor and discharges into the tank, and another rises 4.5 feet to a shower bath. The flow from the upper pipe January 30, 1914, was 10.9 gallons per minute. The flow from the lower pipe would be greater. The temperature of the water January 24 was 103°. The water is used for the swimming tank and is also sold in receptacles to the town people for domestic use.

Ed Boyd.—Location, section 26, T. 15 S., R. 15 E. (within city limits). Has 2-inch (inside diameter) screwed casing, but is reduced at surface to ¾-inch (inside diameter) pipe, on which the tests were made. The pressure, flow and temperature were measured January 30, 1914.

Hazzard and Strang.—Located in lot 89, in section 25, T. 15 S., R. 15 E. Drilled in 1910. Depth of well 873 feet. It penetrates two water-bearing strata, one between 400 and 500 feet and another between 600 and 700 feet. Found sand from 851 to 863 feet. The well carries Layne and Bowler screen of 7.64 inches mesh in both water-bearing strata. The flow in January, 1911, measured with a weir, was 9.3 miner's inches, or 83.7 gallons per minute. The pressure and temperature were measured March 2, 1914. The water is put to domestic and stock uses only, being piped to a large number of houses in the vicinity.

W. B. Hill.—Location of well in lot 38, section 32, T. 15 S., R. 16 E. Drilled in 1912 by J. D. McNeil. No screen was used. The starter contains slots 6 inches long, ranged 6 around the casing, one girdle to each foot. The pressure and other tests were made March 2, 1914. The water is put to domestic and stock uses.

F. S. Best.—Location of well, lot 38, section 32, T. 15 S., R. 16 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter contains 6-inch slots, ranged in rows of 6 around the casing, one row to each foot. The pressure, temperature and flow were determined March 2, 1914. The water is used for domestic and stock purposes. The Best and Hill wells are about one half mile apart and were drilled to about the same depth. The water of the two is stated, however, to taste quite different.

W. A. Thompson.—Location, lot 147, section 31, T. 15 S., R. 16 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter contains 6-inch slots, ranged six in a row about the casing and one row to each lineal foot. The pressure, flow and temperature were determined March 2, 1914. The water is used for domestic and stock purposes.

Alamo School.—Located in lot 78, section 15, T. 16 S., R. 16 E. Drilled in 1912 by J. D. McNeil. The starter used consisted of 6-inch slots placed six around the pipe and one girdle to each foot in length. No screen was used. A water stratum encountered at 200 feet in depth was pump water only. The casing is 4-inch (outside diameter) screwed, but is reduced at the surface to 1.5-inch (inside diameter) pipe, on which the tests were made March 4, 1914. The water is very good to the taste, and is used for domestic and stock purposes.

Central School.—Located in lot 60, section 20, T. 15 S., R. 16 E. Drilled in 1911 by J D. McNeil. Depth of well 827 feet 4 inches, which is the bottom of a stratum of water-bearing sand 29 feet thick. The soil passed through consisted of layers of silt, clay and sand, with some adobe. The water stratum consisted of fine sand. A starter was used about 14 feet long, with slots 6 inches long placed six rows around, one girdle to each lineal foot. Thus the number of slots is 84. When the well was visited March 4, 1914, the water was leaking at a joint about 3 feet from the ground and was not overflowing the top; hence no tests could be made.

C. D. Manning—Located in lot 92, section 22, T. 15 S., R. 15 E. Drilled in 1913 by J. D. McNeil. Has 2-inch (inside diameter) screwed casing. The well was drilled to a depth of 994 feet, but no flowing water was found. Water strata were encountered between depths of 124 and 145 feet, 463 and 483 feet, 506 and 522 feet, and 539 and 551 feet.

Rose School.—Located in lot 170, section 18, T. 15 S., R. 15 E. Drilled in 1912 by J. D. McNeil. There were two wells, the logs of which are similar. One was a 4-inch well and was a failure because a gas explosion jammed the casing. Then a 2-inch well was put down to the same depth. On March 7, 1914, the water was standing 48 inches above the surface in a pipe 54 inches high; hence the pressure at the surface was 1.73 pounds per square inch. The well flowed over the pipe for one year after being bored. The temperature of the water is reported to have been about 109° when flowing and the discharge about 1 gallon per minute.

Ed Gorman.—Located in lot 65, section 17, T. 15 S., R. 16 E. Drilled in 1912 by J. D. McNeil. A stratum encountered at 636 feet was pump water and was cased up. The starter contained 6-inch slots six around the casing and one girdle to each lineal foot. This water is used for domestic purposes and is piped to about 20 stock troughs. It was not feasible to measure the pressure or flow. These were stated to be similar to the Hooker and Bell well, described elsewhere in this report.

Theo. Prim.—Located in lot 100, section 24, T. 15 S., R. 15 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter has 6-inch slots ranged six in a row about the casing, the rows being one to each foot. The pressure and other tests were made January 26, 1914. The water is used for domestic and stock purposes.

A. L. Hickey.—Location, lot 148, section 19, T. 15 S., R. 16 E. Drilled in 1912 by J. D. McNeil. No screen was used. The starter used contains 6-inch slots arranged six in a row around the casing, one row to each foot of casing. After the well was drilled the flow became obstructed and the owner pulled out two sections of casing, thereby reducing the depth by about 41 feet. The pressure and temperature were determined January 27th and the flow January 30, 1914. The water is put to domestic and stock uses.

C. C. Skilling and E. R. Gorman (Carter well).—Location, lot 55, section 19, T. 15 S., R. 16 E. Drilled by A. L. Holt. No screen was used. The starter contains $\frac{3}{8}$-inch drilled holes 1 foot apart, there being from 54 to 60 to the joint.

Log:

Material	Depth to which extends, feet
Clay	157
Sand	323
Clay	510
Sand	530
Clay	665
Sand	680
Clay	703
Sand	710
Clay	733
Sand, carrying some water, but none to speak of	774
Clay	848
Water-bearing sand	883
Clay	950

On January 27, 1914, the pressure and other tests were made. The water is used for domestic and stock purposes.

F. M. Ferguson.—Location, lot 128, section 12, T. 15 S., R. 15 E. Drilled in 1912 by J D. McNeil. No screen was used. The starter contains 6-inch slots ranged six in a row around the casing, one row to each foot. The well is 900 feet deep, there being a 38-foot stratum of water-bearing sand at the bottom. The remainder is sand, silt and clay. At a depth of 200 feet there was found a stratum of water 30 feet thick which resulted in a big flow, stated to be 75 gallons per minute, but the water was brackish and the stratum discarded. On January 28, 1914, the pressure and other tests were made. The water is used for domestic and stock purposes.

Eastside School.—Location, lot 128, section 11, T. 15 S., R. 15 E. The depth, as reported by Mr. Ferguson, of Holtville, is 281 feet. The pressure, flow and temperature were determined January 28, 1914. It was necessary to measure the flow at the outlet of a 1.5-inch (inside diameter) pipe 220 feet from the well and 5 feet from the surface. The water is used primarily for domestic purposes, and to irrigate a few trees in the school yard.

Hooker and Bell.—Location, lot 72, section 7, T 15 S., R. 16 E. Drilled in 1912-1913 by J. D. McNeil. No screen was used, but the starter contains 6-inch slots ranged six around in a row, one row to each lineal foot. On January 27, 1914, the pressure, flow and temperature tests were made. The water is used for domestic and stock purposes.

J. W. Bridenstine.—Location, lot 77, section 8, T. 15 S., R. 16 E. Drilled in 1912 by J. D. McNeil. No screen was used. The starter has 6-inch slots ranged six in a row around the casing, with one row to each foot. On January 27, 1914, the pressure, discharge and temperature were determined. The water is used for domestic and stock purposes.

John L. McMinn.—Location, lot 79, section 6, T. 15 S., R. 16 E. Drilled in 1912 by J. D. McNeil. No screen was used. The starter contains 6-inch slots, ranged six in a row around the casing, one row to each foot. No water was found below 492 feet. The pressure and other tests were made January 29, 1914. The water is used for domestic and stock purposes.

W. A. Thompson.—Location, lot 77, section 7, T. 15 S., R. 16 E. Drilled in 1912 by J. D. McNeil. No screen was used. The starter has 6-inch slots ranged six in a row about the casing, with one row to each foot thereof. The various tests were made January 30, 1914. The water is used for domestic and stock purposes.

Fuller Bros.—Located in lot 127, section 2, T. 15 S., R. 15 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter contains 6-inch slots ranged six in a

row around the casing, with one row to each foot. On January 28, 1914, the pressure, flow and temperature were determined. The water is used for domestic and stock purposes.

B. Rohrer (Stroven well).—Located in lot 143, section 1, T. 15 S., R. 15 E. Drilled by Coachella Valley Development Company. On January 29, 1914, the flow and temperature were determined and on January 30th the pressure. The water is used for domestic and stock purposes.

J. H. Cox.—Location, lot 154, section 3, T. 15 S., R. 15 E. Drilled in 1912 by Coachella Valley Development Company. It has 4-inch (outside diameter) screwed casing, reduced beneath the surface to ¾-inch (inside diameter) pipe on which the tests were made January 28, 1914. The depth of the well, as reported by the owner, is 300 feet, there being a stratum of water-bearing very fine sand 20 feet in thickness at the bottom. There were 2 or 3 other water-bearing strata. A Layne and Bowler starter was used, without a screen. The water is used for domestic and stock purposes.

O. N. Shaw.—Location, lot 74, section 27, T. 14 S., R 15 E. Drilled in 1914 by J. D. McNeil. No screen was used. The starter contains 6-inch slots ranged six in a row about the casing and one row to each foot. The flow was obtained at 200 feet in depth, the water coming through small veins of sand. The pressure, discharge and temperature were determined March 3, 1914. The water is used for domestic and stock purposes primarily. When visited, however, the flow was draining into a corn field which it was slowly irrigating.

Lucy Painter.—Location, lot 88, section 27, T. 14 S., R. 15 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter contains 6-inch slots placed six in a row about the casing, with one row to each foot in depth. A stratum of water 18 inches thick was encountered at 170 feet, this being the flow utilized. The various tests were made on 1.5-inch (inside diameter) pipe March 3, 1914. The water is used for domestic and stock purposes.

D. R. Raymond.—Location, lot 96, section 23, T. 14 S., R. 15 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter has 6-inch slots ranged six in a row around the casing, the rows being one to each foot. The several tests were made March 3, 1914. The water is used for domestic and stock purposes.

L. B. Rogers.—Location, lot 87, section 27, T. 14 S., R. 15 E. Drilled in 1913 by J. D. McNeil. No screen was used. The starter has 6-inch slots, ranged six in a row around the casing and one row to each foot. The pressure, flow and temperature were determined March 3, 1914. The water is used for domestic and stock purposes, and also to irrigate a few trees.

A. L. Storey.—Location, section 15, T. 15 S., R. 16 E. This is under the High-line Ditch. Drilled October, 1913, to March, 1914, by A. L. Holt. No screen was used, but the starter contains ⅜-inch drilled holes 1 foot apart, there being 54 to 60 holes to the joint.

Log:

Material	Depth to which extends, feet
Clay	200
Dry sand	240
Clay	515
Water-bearing sand	530
Clay	960
Dry sand	990
Then clay. Depth of well, 990 feet.	

The flow at 530 feet was utilized and overflowed a pipe 16 feet from the surface. The pipe was then taken off and the flow suddenly ceased, but by pumping the sand it was started again. When the well was visited March 4, 1914, the water was carrying considerable sand and the flow had attained about one fourth its former volume, with prospects that the water would clear and would attain its previous flow. It was impossible to make any tests. This water has no mineral taste and is excellent, being reported to be the best found on the east side. A rotary well rig was being used.

J. M. Prim.—Located under the Highline Ditch in lot 49, section 22, T. 14 S., R. 16 E. Completed in March, 1911, by J. D. McNeil. Depth of well was 964 feet. The soil passed through was all clay, except a stratum of water-bearing sand 14 feet in thickness at a depth of 950 feet. A Layne and Bowler starter without screen was used The pressure, flow and temperature were determined March 3, 1914. The well is used for domestic and stock purposes. It overflows the top of the casing and has created a marsh.

T. B. Shank.—Location, lot 129, section 4, T. 14 S , R. 15 E. Drilled in July, 1909, by Coachella Valley Development Company. Slots were cut in 14 feet of the pipe and a double thickness of ordinary wire screen was wrapped around it to admit the water. The log, as reported by the owner, follows:

Material	Depth to which extends, feet
Soil	4
Dry sand	54
Soil (clay)	291
Water-bearing sand	305

On March 6, 1914, the pressure and other tests were made. The water is used for domestic purposes.

Chas. Phegley.—Location, lot 42, section 34, T. 13 S., R. 15 E. Drilled in October, 1910, by Coe. Slots were made in the last casing and wrapped with very fine wire. No log is available, but the owner reports that formations of sand, slit and clay were passed through to a depth of 285 feet; then a 40-foot stratum of water-bearing sand was encountered and 30 feet of this was cased, making the depth of the well 315 feet. The tests of pressure, discharge and temperature were made March 6, 1914. The water is used for domestic purposes.

Magnolia School.—Location, lot 49, section 33, T. 13 S., R. 15 E. Drilled in August, 1910, by Coe. No log available, but the depth is reported by Chas. Phegley as 347 feet, there being a stratum 7 feet thick of quicksand formation at the bottom. On March 6, 1914, the pressure, flow and temperature tests were made on a ¾-inch (inside diameter) pipe. The water is used for domestic purposes.

Alamario.—Owned by V. E. Stockwell, located in lot 156, section 31, T. 13 S., R. 15 E. Drilled in 1911 by Coachella Valley Development Company. Has 4-inch (outside diameter) screwed casing, but is reduced to 2-inch (inside diameter) pipe at the surface, on which the tests were made. The owner reports the depth as 535 feet. The first 200 feet is silt, then 50 feet of heavy joint clay, then heavy granite gravel bearing water for 10 feet. Another water-bearing stratum of sand 18 feet thick lies

at the bottom of the well. It is stated that the water when discharged has a slight taste of sulphur which lessens after a few minutes' evaporation. On February 5, 1914, the pressure, flow and temperature were determined. The water is used for domestic and stock purposes.

TABLE

Summary of data on flowing wells, east

Name	Year completed	Size of casings, inches	Depth in feet	Location of artesian strata
City of Holtville	1909	4	1,410	836 to 848; 1,100 to 1,120
City of Holtville	1909	2	852	838 to 852
City of Holtville	1911	4	1,098	851.5 to 852; 1,094 to 1,098.
Holtville Natatorium	1910	4	862	848 to 862
Ed. Boyd	1910	4	873	Between 400 and 500
Hazzard and Strang				Between 600 and 700
W. B. Hill	1912	2	861	794 to 817
F. S. Best	1913	2	809	772 to 809
W. A. Thompson (near city)	1913	2	813	793 to 803
Alamo School	1912	4	877	864 to 877
Central School	1911	4	827	798 to 827
Rose School	1912	2	965	796 to 875
Ed. Gorman	1912	2	846	808 to 846
Theo. Prim	1913	2	898	869 to 898
A. L. Hickey	1912	2	658	609 to 658
Skilling and Gorman		2	950	848 to 883
F. M. Ferguson	1912	2	900	862 to 900
Eastside School		2	281	
Hooker and Bell	1913	2	695	664 to 695
J. W. Bridenstine	1912	2	488	475 to 488
John L. McMinn	1912	2	852	469 to 492
W. A. Thompson	1912	2	517	477 to 499
Fuller Bros.	1913	2	937	859 to 865
B. Rohrer		2	580	560 to 580
J. H. Cox	1912	4	300	280 to 300
O. N. Shaw	1914	2	271	200
Lucy Painter	1913	2	247	169 to 170
D. R. Raymond	1913	2	229	200 to 229
L. B. Rogers	1913	2	310	224 to 228
A. L. Storey	1914	2	990	515 to 530
J. M. Prim	1911	4	964	936 to 950
T. B. Shank	1909	4	305	291 to 305
Chas. Phegley	1910	2	315	285 to 325
Magnolia School	1910	2	347	340 to 347
Alamario	1911	4	535	517 to 535

45.

side of Imperial Valley, February, 1914.

Elevation of surface, feet	Discharge, gallons per minute	Pressure at surface, pounds per square inch	Temperature of water, degrees Fahrenheit	Use to which put	Notes
—15	48.0	-------	111.5	Domestic.	
—15	7.5	3.65	101	Domestic.	
—15	2.54	-------	98	Domestic.	
—15	10.9	7.95	103	Domestic and swimming	Discharge measured at upper outlet in 2-inch pipe. That at lower outlet would be greater.
—29	.32	1.43	82	Domestic	Discharge in ¾-inch pipe.
—18	83.7	12.93	103	Domestic.	
—13	15.0	17.23	98	Domestic.	
—13	18.3	7.80	100	Domestic.	
—14	3.0	1.65	96	Domestic.	
+9	1.67	11.30	92	Domestic	Discharge 147 inches from surface in 1.5-inch pipe.
—24	-------	-------	-------	Domestic.	
—97	-------	1.73	-------	Domestic	Water standing in pipe.
—29	-------	-------	-------	Domestic	Reported similar to Hooker and Bell well.
—35	34.4	14.00	105	Domestic	Discharge 66.8 feet from well.
—29	.74	15.07	83	Domestic	Discharge 9.6 feet from surface.
—28	20.7	14.67	103	Domestic.	
—59	60.0	31.67	106	Domestic.	
—65	7.7	7.69	84	Domestic and irrigation	Discharge in 1.5-inch pipe 220 feet from well.
—41	46.2	19.73	98	Domestic.	
—37	7.5	10.00	90	Domestic.	
—47	12.76	8.90	91	Domestic	Discharge 9 feet from surface.
—55	2.86	16.18	89	Domestic	Discharge 21.2 feet from surface.
—60	11.53	30.80	103	Domestic	Discharge 15.7 feet from surface.
—66	50.0	27.00	104	Domestic.	
—85	1.57	9.43	72	Domestic	Discharge in ¾-inch pipe.
—93	7.5	4.44	81	Domestic.	
—93	1.54	3.16	80.5	Domestic	Discharge in 1.5-inch pipe.
—80	3.57	6.96	82	Domestic	Discharge 82 inches from surface.
—100	13.1	14.50	84	Domestic and irrigation.	
—5	-------	-------	-------	Domestic	About to be completed when visited.
—17	15.4	4.08	117	Domestic.	
—119	6.67	5.87	85.5	Domestic.	
—107	.118	2.65	76	Domestic.	
—115	.233	2.26	79.5	Domestic	Discharge in ¾-inch pipe.
—137	33.35	15.00	93	Domestic	Discharge in 2-inch pipe.

Area No. 2.

This area lies between Area No. 1 on the east and the old beach line on the west and extends from Mexico north to Imperial Junction. It includes the central, western and northern portions of Imperial Valley. No flowing water has been found in this area at any depth, although one well at Brawley was drilled to a depth of more than 2,000 feet. It is noteworthy that only four miles east of this Brawley drill-hole an excellent flowing well was drilled at Alamario.

Many shallow wells have been dug near the mouth of Alamo River which give water at 12 to 15 feet in depth. The water probably seeps from New and Alamo rivers.

The logs and other data relative to wells drilled in this area follow:

City of El Centro.—No flowing water was obtained. The following, furnished by Helge Thenberg, is the log of this well for a portion of its depth, drilled in 1910 by the Coachella Valley Development Company:

Log:

Material	Depth to which extends, feet	Material	Depth to which extends, feet
Soil	30	Sand	650
Sand	80	Clay	660
Clay	90	Sand	675
Sand	140	Clay	738
Clay	228	Conglomerate	752
Sand	239	Clay	800
Clay	340	Sand	808
Sand	350	Clay	908
Clay	415	Conglomerate	916
Sand, water-bearing	501	Sand	935
Clay	600	Sandstone	1,015
Sand	610	Gravel beyond	
Clay	645		

The elevation is –49 feet.

Imperial Land Company.—Located on Imperial townsite. Depth, nearly 800 feet. Bored January, 1905, by Enterprise Well Company of Coachella. Used hydraulic rig of light weight and made hole with 6-inch auger on 2-inch pipe. No water struck whatever.

Log: From 1 to 400 feet, alternate strata of adobe or clay and sandy loam. From 400 to 800 feet, the same except about every 50 feet was found a stratum of hardpan from 6 to 12 inches in thickness which was nearly as hard to drill through as soft rock. The elevation is –67 feet.

City of Brawley.—Drilled in 1910 with hydraulic rig by Coachella Valley Development Company. Cased in only 2 strata that would otherwise cave, one at 1,100 feet and the other near the bottom. The upper casing is 8 and the lower 6 inches in diameter. Penetrated sandstone from 590 to 920 feet, but encountered no gravel. The well is 2,032 feet deep and dry. The elevation is –116 feet.

Dixieland.—Location, southwest quarter of section 7, T. 16 S., R. 12 E. Depth of well, as reported by Mr. Hudson, 787 feet. A small quantity of brackish water was struck at 400 feet, in several strata 3 to 5 inches thick. Water-bearing gravel was struck at 787 feet, and there the tools were stuck. Sand, silt and clay were penetrated. No flowing water was obtained.

Area No. 3.

This area encircles Superstition Mountain and includes the plain between the mountain and Carrizo Canyon. No artesian water has been obtained in the area. Several wells have been drilled to considerable depths and the water comes to about 20 feet from the surface in some. A project is on foot to irrigate a considerable area by pumping from the wells.

Data on the individual wells follow:

Earl Garrettson.—Location, south half of section 2, T. 15 S., R. 10 E. Drilled in 1913 by J. D. McNeil. Passed through sandy, gravelly soil to a depth of 20 feet 4 inches; then water-bearing sand to 40 feet 8 inches; then gravelly hardpan to 82 feet 11 inches. No flowing water was obtained.

Hudson—Location, southeast corner of section 25, T. 14 S., R. 10 E. Drilled in 1913 by Borden and Brown, using a cable rig. Depth of well, as reported by owner, 450 feet. Size of casing, 10 inches. Small strata of water-bearing sand were penetrated at various depths. The water rises to 20 feet from the surface. The well is pumped with an air compressor operated by a 40 horse-power engine, which is too small for the compressor. The water is a little salty, but will be used for the irrigation of several hundred acres if possible.

Hudson.—Location, near northeast corner of section 25, T. 14 S., R. 10 E. Drilled in 1913 with cable rig by Borden and Brown. The well has 10-inch casing and is stated by the owner to be 150 feet deep. The casing buckled and the well was abandoned, although the water rose to within 20 feet of the surface. Small strata of water-bearing sand were penetrated, yielding water a little salty.

Hudson.—Location, near northeast corner of section 25, T. 14 S., R. 10 E.; being 200 feet south of the other well in this corner. This was drilled in 1913 by Borden and Brown. The casing was taken up because of damage to the casing in the 150-foot well. The depth, as reported by Mr. Hudson, is 250 feet. The water rises to 20 feet from the surface. Several small strata of water-bearing sand were encountered, the water being a little salty.

Area No. 4.

This area comprises San Felipe Valley below sea level. It is here that the Harper well, also known as the Mesquite Drill-Hole, is located. This is the only flowing well on the west side of the valley and in the entire valley outside of Area No. 1. Other deep wells have been drilled in this vicinity and the belief prevails that artesian water is present in considerable quantity.

There is an abundance of surface or subsoil water in lower Carrizo Creek Valley, but the water in the majority of the wells is reported to be salty and undesirable for either domestic use or for irrigation.

In general, the subsoil or surface water in that section of the desert near the junction of San Felipe and Carrizo creeks is salty and unfit for irrigation. It is reported that 25 or 30 wells are dug in this region where water is obtained at from 25 to 36 feet. Two open wells were dug on the projected San Felipe townsite (section 8, T. 13 S., R. 10 E.) which reached good water at 35 to 40 feet. Other wells dug near San Felipe reach good water at from 24 to 42 feet in depth. Wells near the lower end of Carrizo Creek reach water at 34 to 48 feet. Rush and Owens excavated to a depth of 60 feet near sea level at the east side of Carrizo Creek Valley, striking gravel, but no water.

Data on wells drilled in this area follow:

Harper's or Mesquite Well.—Location, junction of Carrizo and San Felipe creeks, near the southwest corner of the northwest quarter of section 35, T. 12 S., R. 10 E., S. B. M. This was drilled about 1899 by John H. Harper for oil. No oil was found, but a flow of good artesian water was developed. It was formerly possible to locate the site by means of a derrick.

The log, furnished by Ed. Rausin, follows:

Material	Depth to which extends, feet
Silt	150
Sandstone	275
Gravel	320

The well has 6-inch (outside diameter) casing. On February 4, 1914, the temperature of the water was 80°F., and the flow 4 gallons per minute. The flow was originally much stronger and has been reduced by the partial filling up of the well or by the depletion of the underground water. Another 6-inch casing close to the flowing well is now choked up.

The elevation of the surface is –100 feet.

Grace Ambrook.—Location, near southwest corner of southwest quarter of section 35, T. 12 S., R. 9 E. Depth of well, as reported by Ed Rausin, over 500 feet. This was a perfectly dry hole, entirely in clay and soil.

J. P. Loftus.—Location, 640 feet north of the southwest corner of the southeast quarter of section 6, T. 13 S., R. 10 E., S. B. M. Drilled in 1913 by H. J. Sternberg.

Log:

Material	Depth to which extends, feet	Material	Depth to which extends, feet
Soil	34	Coarse water sand	175
Water sand	40	Hard red clay	223
Clay	51	Quicksand	243
Water sand	61	Red clay	260
Soft clay	83	Very sticky slate-colored clay	305
Coarse water sand	89	Red clay	341
Clay	101	Hard red clay	361
Dead sand	107	Hard dark red clay	409
Water sand	113	Hard slate-colored clay	427
Gravel and floating clay, with not much water	117	Fine clay	431
Sand	135	Hard red clay	449
Fine gravel	149	Clay	529
Clay	159	Water, sand and gravel	612
Heaving water sand	169	Sand and clay	661

At the depth of 661 feet the tools were buried by a shooting up of the water, carrying sand. The casing was cut in the stratum from 529 to 612 feet. The surface or subsoil water stands at a depth of 30 feet and the well water at 24 feet. The lower water-bearing stratum contains an abundance of water, as indicated by the pressure, and the prospects seem good for securing flowing water. Another hole will probably be drilled.

L. A. Lindscogge.—Location, southeast corner of the southeast quarter of section 5, T 13 S., R. 10 E. This well was drilled hydraulically in 1910–1911 by H. J. Sternberg to a depth of about 661 feet. The strata penetrated were about the same as in the Loftus well, except that gravel struck at 169 feet in the Loftus well was struck here at 210 feet. From 305 to 409 feet were found sand and gravel mixed with soil, with no water. The tools were stuck at 661 feet.

L. H. Mitchell.—Location, section 8, T. 13 S., R. 10 E. Drilled in 1910-1911 with rotary rig by H. J. Sternberg. This well went to a depth of 660 feet, where the tools were stuck by an upheaval of sand from water pressure, as in the Loftus and Lindscogge wells. A 4-inch bit was used on a 2-inch drill rod. In this well, soft sandstone occurs at about 400 feet instead of clay, as in the Loftus well.

H. J. Sternberg.—Location, near southeast corner of southwest quarter of section 10, T. 13 S., R. 10 E. Drilled in 1912 by owner, using rotary hydraulic rig. Has 6-inch casing. This well was 510 feet deep. Surface water was struck at 45 feet and stands at that depth; then clay to 80 feet. At 320 feet water was struck that stands in the well at the same depth as the surface water. Sand and clay were found to 400 feet, and from there to 510 feet boulders were encountered which prevented deeper boring. The stratum at 320 feet has been pumped for a year, but the pump is not large enough to test the capacity of the well. In an attempt to withdraw the casing it was pulled apart and salty surface water allowed to enter the well, resulting in a mixture of waters unfit for use.

Cawston Ostrich Farm.—Location, 5 miles from San Felipe. Drilled in 1909–1910. Ed Rausin reports that 100 feet of silt and then 400 feet of clay were passed through. No water was found.

Area No. 5.

This area includes the foothill country around Carrizo Canyon and Coyote Creek and the broken Yuha Desert. No flowing water has been obtained here. It was originally 14 feet and is now 26 feet to water in Coyote Wells. Other open wells along Coyote Creek reach water at 7 to 15 feet. Water rises to the surface in Carrizo Canyon and sinks into the sand within 2 miles of the springs. The water from Carrizo Springs is slightly salty, but some of it is used by Mr. P. B. Fuller for irrigation of alfalfa with fair results. Good water is found 1 foot from the bed of the wash at Yuha Springs.

The wells drilled in this area are as follows:

Barrett Drill Hole.—Location, section 11, T. 15 S., R. 9 E. This was drilled by Barrett, and bought by J. M. Holloway. It was drilled for oil, but none was found. Ed Rausin reports that at a depth of about 400 feet the tools were hung up. The soil penetrated was mostly clay. Some water was struck, but it was very bad. Water rose to 40 or 50 feet from the surface.

Henry E. Walker.—Location, at Coyote Wells. One well of 12-inch casing was dug 30 feet deep and another of 4-inch casing 65 feet deep. Water stands at 12 feet from the surface. The 2 wells are reported to deliver 15 miner's inches when pumped with a No. 2 centrifugal pump and 3 horsepower gasoline engine. A windmill with pump and reservoir is also used. The water from the 30-foot well is salty, while that from the 65-foot well is fairly good, indicating that better water is obtained from the lower level.

Yuha Drill Hole.—Location, section 32, T. 16 S., R. 11 E. Drilled in 1909–1910 for oil to a depth of 1,200 feet. Twelve-inch (outside diameter) casing was used to a depth of 300 feet, after which the size was gradually reduced. At a depth of 800 feet an explosion of gas collapsed 3 joints of pipe; this was drilled out and the well extended. Numerous caves occurred. Some oil was reached at 700 feet and oil sand was found at several points, in addition to plenty of water unfit for use.

Another well 14 feet from the first gave an explosion at the same depth. This well is 1,375 feet deep, having penetrated oil and asphalt at several depths. Water rose to 80 feet from the surface.

Hanna Drill Hole.—Located at the northwest base of Fish Creek Mountain. This was a dry hole or did not reach water of good quality.

Area No. 6.

This area comprises the valley lands in Mexico. Water has been found in several wells along the Inter-California Railway, but most of it is not good for domestic or boiler use.

Data on the individual wells, furnished by the Southern Pacific Company, follow:

Sesbania.—Location, 14.2 miles from Calexico; 120 feet right of Sta. "D," 2,881+43. Owned by Southern Pacific Company. No indications of water were found and the well was abandoned. The depth was 559.6 feet.

Log:

Material	Depth to which extends, feet	Material	Depth to which extends, feet
Light soil (silt) mixed with clay	19.7	Clay and sand	252.4
Sand and clay	39.3	Sand	272.2
Clay	57.8	Clay and sand	291.3
Sand and clay	100.0	Sand	329.5
Clay	135.3	Clay and sand	368.5
Sand and clay	154.4	Clay and rock	386.8
Clay	192.6	Clay	424.9
Clay and sand	211.6	Clay and rock	539.8
Sand	231.4	Rock	559.6

The elevation of the ground surface is 1,161.1 in reference to Inter-California Railway levels.

Hechicera.—Location, 23.1 miles from Calexico; 97 feet right of Sta. "L," 3,561+75. Owned by Southern Pacific Company.

Log:

Material	Depth to which extends, feet	Material	Depth to which extends, feet
Light soil mixed with clay and sand	19.0	Gravel	153.3
Clay	57.4	Sand and gravel	158.2
Sand	145.3	Good water-bearing gravel	172.2

A good flow of water occurs at the depth of 172.2 feet which is unfit for use in locomotive boilers. It seems to be good domestic water. The water is raised by a hand pump for domestic use.

Analysis	Grains per gallon
Calcium carbonate	9.97
Magnesium carbonate	2.63
Calcium sulphate	28.34
Magnesium sulphate	12.60
Calcium chloride	.00
Magnesium chloride	4.72
Calcium hydroxide	.00
Silica and oxides of iron and al.	2.39
Incrusting solids	60.65
Alkali carbonates	.00
Alkali sulphates	.00
Alkali nitrates	.00
Alkali chlorides	77.27
Organic matter	.00
Non-incrusting solids	77.27
Total solids	137.92

The elevation of the ground surface is 1,180.9 in reference to Inter-California Railway levels. The elevation above sea level of Hechicera is 51 feet.

Cuervos No. 1.—Location, 42.2 miles from Calexico; 100 feet right of Sta. "C," 4,535+50. Owned by Southern Pacific Company.

Log:

Material	Depth to which extends, feet
Light soil mixed with clay and sand	20.0
Sand	96.8
Sand and clay mixed with light gravel	115.9
Good water-bearing gravel and rock	120.9

A good flow of water was obtained. This was put down as a test well and was not cased. The well has caved and is destroyed. The elevation of the ground surface is 1,227.1 in reference to Inter-California Railway levels.

Cuervos No. 2.—Location, 42.2 miles from Calexico; 50 feet right of Sta. "C," 4,546+00. Owned by Southern Pacific Company.

Log:

Material	Depth to which extends, feet	Material	Depth to which extends, feet
Silt	10	Sand	101
Fine sand	12	Gravel	103
Clay	51	Sand	118
Packed sand	81	Good water-bearing gravel	124
Fine sand	87		

The water rises to within 13 feet of the ground surface. The water is unfit for boiler use and untreatable chemically. It is not used.

Analysis	Grains per gallon
Calcium carbonate	11.31
Magnesium carbonate	2.86
Calcium sulphate	3.27
Magnesium sulphate	3.32
Calcium chloride	.00
Magnesium chloride	.00
Calcium hydroxide	.00
Silica and oxides of iron and al.	1.11
Incrusting solids	21.87
Alkali carbonates	.00
Alkali sulphates	.41
Alkali nitrates	1.22
Alkali chlorides	13.30
Organic matter	.00
Non-incrusting solids	14.93
Total solids	36.80

The elevation of the ground surface is 1,227.8 in reference to Inter-California Railway levels.

Bataques.—Location, 28.1 miles from Calexico; 106 feet right of Sta. "L," 3,821+45. Owned by Southern Pacific Company.

Log:

Material	Depth to which extends, feet	Material	Depth to which extends, feet
Silt	39.1	Rock	175.2
Sand and clay	58.8	Sand	233.3
Clay	77.7	Sand and clay	364.4
Sand	96.8	Rock and clay	403.4
Sand and clay	117.1	Clay	422.6
Sand	135.4	Rock	441.6
Water gravel	143.4	Clay and rock	480.7

No water was struck below the water stratum of gravel at 143.4 feet, there being a good flow in the well at that depth. The water is unfit for boiler use and is

untreatable. It is used for drinking, however, by man and live stock. The well is pumped by a windmill.

Analysis	Grains per gallon
Calcium carbonate	14.35
Magnesium carbonate	1.75
Calcium sulphate	10.21
Magnesium sulphate	15.39
Calcium chloride	.00
Magnesium chloride	.00
Calcium hydroxide	.00
Silica and oxides of iron and al.	2.04
Incrusting solids	43.74
Alkali carbonates	.00
Alkali sulphates	.00
Alkali nitrates	.00
Alkali chlorides	56.39
Organic matter	.00
Non-incrusting solids	56.39
Total solids	100.13

The elevation of the ground surface is 1,188.9 in reference to Inter-California Railway levels.

Area No. 7.

This area comprises the mesa east of Imperial Valley proper between the ancient beach line and the sand hills. No artesian water has been obtained here, but several shallow wells have been drilled.

Data on these wells, furnished by Newt Gray, follow:

Newt Gray or Eastside Mesa Well.—Location, ¾ mile north of the international boundary between monuments 209 and 210. The depth drilled was 106 feet; depth to water, 86 feet. Size of casing, 10 inches. In drilling this well 3 strata of clay were encountered from 4 to 8 feet thick. The water is of good quality. The well was drilled to furnish water to travelers on the Yuma trail.

County Well.—Location, section 24, T. 15 S., R. 16 E., 6 miles from the High-line ditch. The depth drilled is not known; depth to water, 54 feet. The water is good. The well was drilled for the use of travelers on the Yuma trail.

Government Well.—Location, section 2, T. 16 S., R. 16. E., 4 miles from the High-line ditch. The depth drilled was 37 feet; depth to water, 30 feet. The water is reported to be good.

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS
IRRIGATION INVESTIGATIONS

MAP OF

IMPERIAL CO.

CALIFORNIA

SHOWING

DRILLED WELLS

-1914-

PREPARED IN CO-OPERATION WITH
STATE ENGINEERING DEPARTMENT OF CALIFORNIA

R.9 E. R.10 E. R.11 E. R.12 E. R.13 E. R.14 E. R.15 E. R.16 E. R.17 E. R.18 E. R.19 E. R.20 E. R.21 E. R.22 E.

T.9 S. T.10 S. T.11 S. T.12 S. T.13 S. T.14 S. T.15 S. T.16 S. T.17 S.

SALTON SEA

Durmid · Bertram · Pope · Frink · Volcano · Palo Verde · Milpitas

Arroyo Seco

ANCIENT BEACH LINE

NILAND · Flowing Wells · Date City · Tortuga · CALIPATRIA · Mammoth · Acolita

San Pedro Cr.

G. A. MORROW · HARPERS WELL · J.P. LOFTUS · L.A. LINDSCOGG · L.H. MITCHELL · H.J. STEWARD

WESTMORELAND · Alberta · No. 5 MAIN CANAL · MAIN CANAL

River Alamo

BRAWLEY · DRILL HOLE · ALAMORIO · MAGNOLIA SCHOOL · O.C. PRESLEY · T.B. SHANK

Mesquite · Glamis · Picacho

SUPERSTITION MOUNTAIN · FISH CREEK · HANNA DRILL HOLE · Carrizo

HUDSON · E. GARRETTSON · GARRETT DRILL HOLE · Keystone · D.R. RAYMOND · J.M. PRIME · Highline · L.B. ROGERS · L. PAINTER · O.N. SHAN

SAND HILLS · Ruthven · Drylyn · Cactus · Ogilby · Salton Dry Lake

WEST SIDE MAIN CANAL · BOUNDARY IRRIGATION DISTRICT · U.S. RESURVEY LINE

IMPERIAL · DRILL HOLE · J.H. COX · FULLER · EASTSIDE · F.M. FOSDICK · D. ROSE SCHOOL · E. GORMAN · A.I. STOREY · COUNTY WELL

New River

COYOTE MOUNTAIN · Coyote Wash

SEELEY · Mobile · EL CENTRO · Meloland · HOLTVILLE · CENTRAL SCHOOL · SAILLING · GORMAN · HAZZARD · STRANG · F.P. HILL · W.A. THOMPSON · NATATORIUM WELL · CITY OF HOLTVILLE · GOVERNMENT WELL · ALAMO SCHOOL

DIXIELAND · DIXIELAND WELL · SILSBEE · HEBER · Coyote · H.E. WALKER · YUMA DRILL HOLE

BRAWLEY MAIN CANAL · No. 5 MAIN CANAL

CALEXICO · Mexicali · Sharps · Diegunos · WELL Cuervos · Paredones · Tecolote

SIGNAL MTN. · WEST SIDE MAIN CANAL · Packard · Pascualito · Sesbania · WELL · Cocopah · Hechicera · WELL · Bataques · WELL · IMPERIAL VALLEY CANAL

M E X I C O

YUMA INDIAN RESERVATION · BARD · Laguna River · Sellew · Knob · Araz · Hanton · KARNAK · Colorado · Andrade · YUMA · Gila River · Igondones · N. GRAY

Colorado

½ 0 1 2 3 4 5 6 7 8 9 10
SCALE OF MILES

WELLS INDICATED THUS ○

WILLIAM M. HUMANS

PART III

State Roads and Highways.

STATE ROADS AND HIGHWAYS.

There are two distinct systems of public highways being acquired by the State of California. One dates from 1895, when the legislature by act declared the road from Placerville to the state line near Lake Tahoe to be a state road; the other had its inception in 1910, when the people by vote authorized the issuance of bonds to the extent of $18,000,000 with which to construct a system of highways throughout the State. The fund so provided, and the construction of the highways thereunder, is being administered by a section of the Department of Engineering delegated for that purpose and designated the California Highway Commission.

For convenience in distinguishing the two systems of highways above described the roads built or acquired under the highway bond act are designated state highways, while the other class is referred to in the records and correspondence of the Department of Engineering as state roads.

Leaving the state highways to be discussed later, a brief description of the state roads is here presented.

STATE ROADS.

The system of state roads, beginning with the acquisition by the state of the Placerville-Lake Tahoe road, as stated above, has been gradually extended from time to time by the taking over to state control of county roads and the construction of new roads in the mountainous regions where the building and maintenance of roads in condition for free travel would be beyond the financial ability of the counties supporting them. The system now embraces eleven roads, each created by a special act of the legislature, and bearing the name usually designated in the act creating it. These eleven roads are situated in thirteen different counties and aggregate about 550 miles in length. The official names and the counties traversed by them are as follows:

Alpine State Highway—El Dorado, Alpine, Mono, Calaveras, and Amador.

Emigrant Gap State Road—Placer.

Kings River Canyon State Road—Fresno.

Lake Tahoe Wagon Road—El Dorado.

Lassen State Highway—Lassen.

Myers Station-McKinney State Road—El Dorado and Placer.

Mono Lake Basin State Road—Mono.

Sierra State Highway—Sierra.

Sonora-Mono State Road—Tuolumne, Alpine, and Mono.

Trinity-Humboldt State Highway—Trinity.

Redwood Park State Road—Santa Clara, San Mateo, and Santa Cruz.

It will be observed that some of the foregoing are called "State Roads," while others are termed "State Highways." There is no reason why all should not be designated by the same term. Most of the names are long and cumbersome, several being compound and far from euphonious, while some are misleading as a designation of locality. Several of these roads traverse localities wherein were enacted much of the romance and tragedy of California's early history, and might appropriately bear names commemorative of those events.

The Emigrant Gap road passes over the high Sierra where the old emigrant trail crossed, having its eastern terminus at Donner Lake. This beautiful little lake was made famous by the perishing of thirty-six immigrants and the near annihilation of the Donner party in the winter of 1846.

Lake Tahoe road, for the greater part, is along the old overland stage road connecting California with "back home" at St. Joseph, Missouri. This is a portion of the road, 1,050 miles long, over which the famous pony express was operated in 1860 and 1861, carrying mail in eight days, as against twenty-two days required for steamship by the way of Panama.

One branch of the Alpine road crosses the range by way of Carson Pass along the trail blazed by the intrepid pioneer, Kit Carson. The "blazes" made by Carson on the trees by the roadside to indicate the way are still visible, as are also the ruts worn in the granite by the wheels of the wagons following the trail. A fit name for this road would be "Kit Carson State Road," and so with others. Each road has some distinction particularly its own, and might well bear a name indicative of such characteristic. Under appropriate names, they would become monuments to commemorate the early history and history-makers of the State.

During the session of the legislature held two years ago the matter of changing the names of state roads to conform to the foregoing suggestion was taken up by the parlors of the Native Sons of the Golden West, a patriotic fraternal order composed of native-born Californians. A bill was introduced, giving names to certain of those roads as suggested above, but it failed to become a law.

LAKE TAHOE WAGON ROAD.

This road was originally a toll road. It was declared to be a state highway by act of the legislature, approved March 23, 1895 (Chapter 128, Statutes 1895), which defined it as "commencing at the junction of the Lake Tahoe wagon road with the wagon road leading from Placerville to Newtown, a short distance easterly from the village of Smithflat, El Dorado County and running thence to Lake Tahoe."

The road was administered by a special commissioner until placed in charge of the Department of Engineering in 1907.

Plate XXXVII. Emigrant Gap Road, Donner Pass, Showing Subway Under Railroad. Railroad Snow-sheds in Middle, State Road in Foreground.

The Lake Tahoe wagon road is 61.91 miles in length from Smithflat to the Nevada state line at the south end of Lake Tahoe. Practically every rod of this road is through a region of great scenic beauty. It is one of the most popular mountain roads open to automobiles, and the increasing traffic over it entails constant vigilance and labor to keep it in good condition. About fifteen miles at the west end is in a material that quickly works into an impalpable dust under the rapidly moving wheels, and it is necessary to sprinkle it daily during the dry season. This required the service of several teams, but this summer a caterpillar traction engine has been used for hauling the sprinkling wagons, and in the one season used saved about $600 over the cost of the same work formerly done with horses. A greater saving is anticipated as soon as better facilities can be installed for loading the wagons.

There has been discovered near the road a bed of gravel which appears to be well adapted for metalling road surfaces. About six miles is being covered with this surfacing which it is believed will be a great improvement.

MONO LAKE BASIN ROAD.

This road starts in Levining Creek canyon a few miles from Mono Lake and follows up the canyon to Tioga Lake, a distance of 9.3 miles, connecting the county road system of Mono County with a road locally known as the Tioga toll road.

This latter road was built under a franchise for a toll road but excepting for a short time immediately following its completion about 1882 or 1884, no tolls have been collected for its use nor has it been kept in condition to induce travel over it.

It is 63 miles in length from Tioga Mine near Tioga Lake to where it joins the Big Oak Flat and Yosemite Turnpike at Sequoia, a short distance from Yosemite Valley, but has been allowed to deteriorate badly. It was reported by the superintendent of the Yosemite National Park that only a little more than $250 had been expended in upkeep by the owners in five years.

A bill was introduced in Congress some years ago to purchase the road for the Yosemite National Park, but nothing has so far come of it.

Without a connection across the mountains the Mono Lake Basin Road is of little value to the State and unless the Tioga Road can be secured and made a free highway it would better be abandoned. With the Tioga road a state road, traversing 52 miles of the Yosemite National Park it would afford a delightful transmountain route through a wonderful scenic region.

Nothing has been done with the state road during the past two years excepting to restore some rock walls crushed by the winter snowslides, repair culverts and general maintenance.

SONORA—MONO STATE ROAD.

This road connects Bridgeport, Mono County, with the centers of population in the Great Valley, terminating as a state road at Long Barn, 20 miles east of Sonora, Tuolumne County.

This road, in common with all of the state roads in the high Sierras, is subject to the ravages of snowslides in winter and washouts by thunderstorms in summer. Cost of maintenance is greatly increased by the hundreds of thousands of sheep, cattle and horses driven to mountain pastures in the spring and returned to the lowlands in the autumn. After each band of stock passes over the road it is found full of rocks dislodged from the hill slopes above by the animals' hoofs.

A great deal of maintenance and renewal has been accomplished. The wooden bridge over the south fork of Stanislaus River at Strawberry gave way last year and has been replaced with a concrete arched bridge.

An old bridge over the main river was crushed by the snow last winter, and this summer a new and stronger timber bridge was erected in its stead.

No changes in alignment have been attempted, though when funds become available such changes may be made with great advantage, particularly at one stretch where several stream crossings can be avoided by changing the location of the road.

TRINITY—HUMBOLDT STATE ROAD.

This road, beginning at Mad River Low Gap near the boundary between Trinity and Humboldt counties, and running thence across Mad River, over South Fork Mountain, across South Fork of Trinity River and up Rattlesnake and Post creeks, over Post Creek Mountain connects at Peanut with a county highway from Red Bluff to Hayfork. The length is 31¾ miles.

Construction began in 1907 and was partly completed in 1912 so that traffic could get over it. Each year since improvements have been made upon it. In addition to the usual repairs and maintenance work, this year two wooden bridges over Post and Salt creeks, respectively, were replaced with concrete structures. During the last summer, also the piers for two bridges, on Mad and Trinity rivers were constructed by the department, and contracts let for the material and erection of the superstructure. Both bridges will be steel deck-truss on concrete piers. It is hoped to have them completed in time for summer travel next year.

RED BLUFF EXTENSION.

The legislature in 1913 appropriated $3,000 for the location and survey of a road from the eastern terminus of the Trinity-Humboldt

Road to Begum Creek near the line between Shasta and Tehama counties.

Three routes were examined, and selection made of a line from Peanut via Bridge Gulch to Wildwood, thence following generally the course of the present road to the summit of Goode's Mountain. From here it leaves the old road, follows the side of Goode's Mountain to the headwaters of Cottonwood Creek; thence down the middle fork of that stream, and across Begum Mountain to Begum Creek at Sylvester's.

The distance from Peanut to Sylvester's by the survey is 36 miles and the maximum grade six per cent.

The cost of construction for 12 feet width of roadway, 18 feet wide on the turns is estimated at $65,000 plus $25,000 for bridges and culverts, making the total estimated cost $90,000.

It is recommended that provision be made for the construction of the proposed extension, contingent on Tehama County obligating itself to continue a road of like grade and character on to Red Bluff.

SIERRA STATE HIGHWAY.

This road, situated in Sierra County, was authorized by act of legislature, approved March 8, 1907, at which time the sum of twelve thousand dollars was appropriated to make surveys and construct a road from Downieville to Mount Pleasant, a distance of 20 miles. During the summer of 1907, a survey was made of 14½ miles of the line, leaving about 5½ miles unsurveyed. Where the right of way was not donated the county of Sierra procured it without cost to the State. In July, 1908, construction was commenced and 2.9 miles of the road was completed. The width of the roadway constructed is 12 feet; turnouts, 18 feet; maximum grade, 6½ per cent.

The cost of building this 2.9 miles of road was $8,018.97. The funds being nearly exhausted, and winter coming on, the tools and equipment used were stored at Downieville. The next summer some repairing was done but owing to lack of funds no construction was attempted, nor has there been any attempt at maintenance during the last two years.

This road, as stated above, would be about twenty miles in length, if completed; less than three miles of it has been constructed at a cost of $12,000. In its uncompleted condition, it does not afford convenience to any considerable number of people, and if completed as originally planned, it will not connect any important centers of population or industrial activity; nor will it afford Downieville a good means of reaching the Sacramento Valley. In view of these conditions the wisdom of expending more money to complete the road or of maintaining as a state road the three miles now built is open to question.

In view of the above statement it is recommended that this road be abandoned as a state road.

KINGS RIVER CANYON ROAD.

This is one of the most expensive roads in the State to construct. Beginning at General Grant National Park in the Kings River region amongst the giant redwoods (sequoia gigantea) it runs in a general easterly direction 32.8 miles to the floor of Kings River Canyon, a counterpart of the famous Yosemite Valley in all scenic features excepting the waterfalls.

Less than one-half of the road has been constructed at a cost of about $75,000. When completed it will afford ingress to the wildest region of the celebrated rugged scenery of the Sierras.

During the last period only maintenance and slight improvements of the roadbed already constructed has been attempted.

EMIGRANT GAP ROAD.

This road, located along the route followed by the ill-fated Donner party and other immigrants coming into California in the pioneer days, begins at Emigrant Gap, in Placer County, through Donner pass to the west end of Donner Lake. Most of the roadbed was constructed at the time the Central Pacific railroad was being built. Just as the road turned down the east slope of the mountains from the summit it crossed the railroad track through a snowshed at the end of a tunnel. The grade descending from the crossing exceeds 22 per cent. This has always been an extremely dangerous crossing, which was recognized by the officials of the railroad company as well as of this department and the traveling public.

The railroad company agreed to contribute part of the cost of eliminating the crossing, and in 1913 the legislature appropriated $4,000, and with this fund and the railroad's contribution the state road was changed, a tunnel was pierced under the railroad track, and in this manner the dangerous grade crossing is avoided. The change was completed last summer much to the relief of all concerned.

The other improvements on the Emigrant Gap road effected consisted of the construction of two small concrete bridges and the substitution of iron culverts for sixty wooden structures.

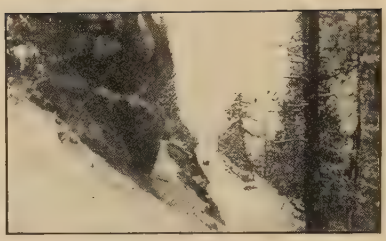
MEYERS-M'KINNEY ROAD (TAHOE).

This road around the west short of Lake Tahoe connects the Lake Tahoe road from Placerville with the wagon road from McKinney's to Truckee, Donner Lake and the Emigrant Gap State Road.

It was authorized by an appropriation made in 1911, and construction was begun in 1912, but it was not until 1913 that it reached a condition permitting travel upon it. Improvements have been added during 1914.

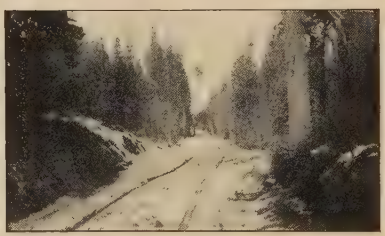
Skirting the west side of the lake affording most entrancing views of that great gem of the mountains, it has become very popular with the mountain tourists.

A Charming View of Lake Tahoe.



'Neath Beetling Crags.

A Rock Slide.



Through a Virgin Forest on a State Road.

A Glacial Lake, Mono Lake Basin.

Where Christmas Trees Grow, Along a State Road.

Plate XXXVIII.

Plate XXXIX. Natural Tunnel on Survey of Eastern Extension of Trinity-Humboldt State Road. The road will run through the tunnel.

LASSEN STATE ROAD.

This road, lying mostly in a region of volcanic soil and boulders, is difficult to maintain. During the last season, the Department in co-operation with the county of Lassen macadamized about 1½ miles of roadbed across a particularly bad stretch.

ALPINE STATE HIGHWAY.

Certain roads traversing the mountain regions in El Dorado, Amador, Alpine, Calaveras and Mono counties constructed by the several counties named, or by toll road companies and later acquired by the counties, were taken over and created a state highway by the act of the legislature, approved April 15, 1911 (Chapter 468, Statutes 1911). The aggregate length of the routes declared by the statute as constituting the Alpine State Highway is about 217 miles and may be divided into three natural geographical sections, as follows: Amador and Alpine counties, 75 miles; Calaveras and Alpine counties, 60 miles; El Dorado, Alpine, and Mono counties, 82 miles.

With the exception of about 24 miles of the Alpine-Mono section, all of the road has been traveled by team and much by automobiles, though there are many steep grades, and, owing to neglect, many miles had become in bad condition on account of slides, washouts and fallen timber. The 24 miles of the Alpine-Mono section mentioned above is mostly new territory not traversed by any kind of road. A survey was made of this portion in 1912 but no funds being available for construction nothing has been done to complete the gap, the cost of which was estimated at $75,000.

The Alpine State Highway traverses mountainous regions, very sparsely inhabited, and the maintenance of it was a heavy burden upon the counties supporting it; heavier in fact than they were able to sustain and as a consequence much of the road had become very much out of repair and required a large expenditure to put it in condition again. Maintenance of these mountain roads is expensive and with the limited funds at command, improvements which could often be effected by change of location could not be accomplished as desired, although some work in that direction has been executed, notably between Lake Tahoe and Hope valleys and on the Carson Pass branch below (west of) Cooks Station. Here in a long stretch of the road where much teaming is done in the summer and heavy rains occur in winter, the combined effect of the wagon wheels and water has worn the roadway into a ditch from 4 to 12 feet deep, and the width at the bottom equal to the tread of the wagons.

It was deemed best here to shift the road to new ground where a roadway was graded, over a distance of about 15 miles, making a very marked improvement.

On the Ebbetts Pass (Calaveras branch) about three miles of roadbed was surfaced with handbroken rock and earth.

In Mono County a concrete culvert was built at the crossing of Little Antelope Creek.

REDWOOD PARK ROAD.

The legislature by an act approved June 13, 1913 (Chapter 398), appropriated the sum of $70,000 for a road from Saratoga Gap in Santa Clara County, through the Coast Range Mountains, to the California Redwood Park.

A survey was made in the early part of last summer and construction began in September last. The total length as surveyed to Governor's Camp, in the Park, is 16 miles. The road runs through Governor's Camp, the resort and camp grounds of the Park, and terminates at Bloom's Mill. From this point the county of Santa Cruz is constructing a road upon a more direct route to Santa Cruz city than any other road now in existence.

Construction on this road is progressing rapidly under the direction of this Department with the prospect that it will be open to traffic before the end of this year.

STATE ROADS ADVISORY COMMITTEE.

The 1913 session of the Legislature adopted Assembly Joint Resolution No. 31 (Chapter 77, Concurrent and Joint Resolutions, 1913), creating an advisory committee consisting of two senators and two members of the assembly—

> "To confer with the state engineer and the state board of control, regarding location, construction and maintenance of state roads other than state highways constructed under and by virtue of the 'state highways act' of California and to report back with recommendations to the forty-first session of the Legislature."

The committee appointed consisted of Senators P. F. Cogswell and Benjamin Rush and Assemblymen W. F. Chandler and A. G. Kuck. This committee, with Mr. Clyde L. Seavey, of the Board of Control, and the State Engineer, made a trip during the autumn of 1913 over all of the roads enumerated in the foregoing description of state roads as well as over the routes of several proposed state roads.

The advisory committee will present a report and its recommendations to the coming session of the Legislature.

ROAD MAINTENANCE FUND.

By provision of the motor vehicle act, one half of the net receipts for motor vehicle licenses is assigned to the State for road purposes. Of the funds received by the State from the source stated, $125,000 was allotted for maintenance and improvement of the state roads above enumerated.

Snow Scene, Lake Tahoe.

"A Friend in Need" Breaking Snow on Emigrant Gap Road.

A View Point on Myers-McKenny Road.

Route of State Road, Before Clearing.

Plate XL.

The acquisition of these funds has enabled the department to maintain and preserve the roads much better than could otherwise have been done, and also enabled the inauguration of all of the improvements above described.

TABLE 46.

EXPENDITURES FOR MAINTENANCE OF STATE ROADS.

NOVEMBER 30, 1912, TO NOVEMBER 1, 1914.

Emigrant Gap State Road—		
65 corrugated iron culverts, cost	$1,287 89	
2 concrete culverts	2,000 00	
Machinery	460 39	
Labor and team hire, etc.	14,861 82	
Total		$18,610 10
Kings River Canyon Road—		
Machinery	$134 24	
Labor, team hire, etc.	3,611 83	
Total		3,746 07
Alpine State Highway—		
66 corrugated culverts	$849 55	
2 concrete bridges	2,500 00	
Machinery	697 33	
Labor, team hire, etc.	29,556 20	
Total		33,603 08
Lake Tahoe State Road—		
10 corrugated culverts	$347 35	
Extension of sprinkling system	606 73	
Machinery	2,473 33	
Labor, team hire, etc.	19,539 35	
Total		22,966 76
Lassen State Highway—		
Machinery	$939 00	
Labor, team hire, etc.	1,706 03	
Labor, team hire, etc., Lassen County	286 00	
Total		2,931 03
Mono Lake Basin Road—		
Machinery	$1,168 29	
Labor, team hire, etc.	8,882 51	
Total		10,050 80
Myers-McKinneys State Road—		
20 corrugated culverts	$434 19	
Machinery	2,844 11	
Labor, team hire, etc.	5,183 54	
Labor, team hire, etc., forest service	500 00	
Total		8,961 84
Sonoma and Mono Road—		
Wooden bridge	$600 00	
Concrete bridges	3,300 00	
Machinery	275 00	
Labor, team hire, etc.	7,836 96	
Total		12,011 96
Trinity State Road—		
10 corrugated culverts	$192 51	
2 concrete culverts	2,500 00	
2 bridges	13,000 00	
Machinery	2,762 93	
Labor, team hire, etc.	9,893 93	
Total		28,349 37

TABLE No. 47.

SUMMARY OF STATE ROAD STATISTICS.

	Miles long	Miles built	Appropriations 1895	1897	1899	1901	1903	1905	1907	1909	1911	1913	Motor Vehicle	Total	Amount expended	Balance Nov. 1, 1914
Lake Tahoe:																
Surveys and construction	62	62	$2,500													
Improvements					$25,000			$6,000	$10,000	$20,000	$15,000					
Maintenance				$10,000	9,200	$9,200	$9,200	9,200		10,000	10,000	$18,000	$9,000	$172,300	$165,784	$6,516
Mono Lake Basin Road:																
Surveys and construction	9	9			25,000		25,000									
Improvements									2,500							
Maintenance								1,000		3,000	5,000	5,000	5,000	71,500	68,760	2,740
Sonora and Mono Road:																
Improvements	78	78						20,000	12,000	10,000						
Maintenance							4,000	8,000	800	12,000	12,000	1,000	8,500	88,300	84,998	3,402
Trinity and Humboldt Highway:																
Survey and construction	33	33					1,800		50,000		50,000	50,075				
Maintenance												10,000	22,200	184,075	175,782	8,293
Sierra and Downieville:																
Survey and construction	20	3							12,000					12,000	11,913	87
Kings River:																
Survey and construction	32	14½						*25,000		25,000	25,000					
Maintenance												4,000		79,000	76,132	2,868
Emigrant Gap Road:																
Survey and construction	28	28								15,000		4,000				
Maintenance											5,000	5,000	8,200	37,200	34,231	2,969
Alpine State Highway:																
Maintenance	217	193									35,000	6,000	33,000	74,000	61,786	12,214
Myers-McKinneys Highway:																
Survey and construction	28	28									25,000	†42,168				
Maintenance												2,000	13,000	82,168	78,626	3,542
Lassen State Highway:																
Maintenance	29	29									5,000		2,000	7,000	5,693	1,307

	Received	Expended	Balance
State Funds	$807,543	$763,705	
Fresno County	12,500	12,500	
Forest Service	500	500	
Totals	$820,543	$776,705	$43,838

*Kings River Canyon Road—state appropriation, $25,000; Fresno County, $12,500; state, $50,000. Total cost, $87,500.
†$500 additional donated by Forest Service.

Plate XLI—A. Building Concrete Bridge for Mountain Road.

B. Concrete Bridge, Salt Creek, Trinity-Humboldt State Road.

The table of partial census referred to above which, it will be observed, shows a very marked increase in travel for 1914 over that in 1913 on most of the roads, here follows:

TABLE No. 48.

Traffic Census, State Roads.

Name of road	Year	Automobile number		Team number		Loose stock number	
		Through	Local	Through	Local	Through	Local
Emigrant Gap	1913	2,200		100		440,000	
	1914	4,500		1,100		440,000	
Myers-McKinneys	1913	10					
	1914	3,000		1,000			
Lake Tahoe	1913	2,919					
	1914	4,405					
Alpine:							
Carson Pass	1913	31	44	45	135		
	1914	199		228	200		
Ebbetts Pass	1913	20	70	158			
	1914	750	1,500	343			
Alpine Trunk	1913	192		146	7		
	1914	331					
Alpine, Mono section	1913	60	300	620	45		10,000
	1914	330	1,060	612			
Sonora-Mono	1913	200	50	100	75	90,000	120,000
	1914	500	360	170	612	98,000	123,000
Trinity-Humboldt	1913	200		50			
	1914	670		150			

EIGHTEEN MILLION DOLLAR STATE HIGHWAYS.

When the people of the State voted to create a bond issue of eighteen millions of dollars to acquire a complete system of state highways, they expressed emphatic declaration that California should be in the vanguard of the march of twentieth century progress.

Although the vote in favor of the measure indicated a deep interest in the subject on the part of the people, it is doubtful if many of them fully realize its importance nor the influence upon industrial development of the State that will be exerted by a system of good roads such as is contemplated by the act.

Much as railroads, rivers and canals are a means for transportation of the commerce of the country, enormous as that commerce is over those highways, they are not so important to the mass of the people as are good roads. Every pound of produce and nearly all merchandise transported over the railroads and waterways must be hauled to the receiving stations, or from the points of debarkation to the depots of distribution, while probably as much more is transported over the roads in inter-community traffic without ever being transferred to the public carriers.

Plate XLII. Building State Highway Through the Forest.

It is held that as a general rule the suitable improvement of a highway within reasonable limitations will double the value of the land adjacent to it and increase that of more distant property within a large radius of influence. Accepting the statement as true, then the entire cost of the proposed system will have been returned to the State many times over in enhanced values long before its completion.

The near perfection of the motor vehicle as a means of transportation, enabling the traveler to go in an hour farther than he formerly went in a day, and making it possible to deliver produce to market in a fresh state from distances that absolutely were impossible to cover with the best animal locomotion, is a factor of great potency which can not be ignored in contemplating future developments.

There are today 120,000 automobiles registered in the State. If one third of them are trucks, there are still 80,000 passenger cars, ranging in size from two-passenger roadsters to the big autobusses carrying 75 passengers. Allowing an average of five passengers to each and a daily run of only ten miles, it aggregates 4,000,000 passenger miles traveled every day. Add to this 40,000 trucks carrying two tons each and running 12½ miles a day gives a million ton miles of freight carried each day by motorpower over the existing roads of the State, good, bad and execrable. These figures are purely speculative. The writer does not know that they represent more or less than the facts, but they are offered to the reader as a basis to figure for himself the importance of this factor in the demands for "good roads" and more of them.

Another factor which may well be considered in this connection is the attraction that good roads will have for the tourist. Some states are spending large sums in betterment of their highways with a view of inducing automobilists from other states to travel over them, and no state in the Union, nor any country in the world, can offer to the tourist such attractions as will be opened to his pleasures in the mountains and at the seashore as California, when she shall have acquired a complete system of good highways.

Europe found long ago that it pays to make its scenic regions accessible over well constructed roads, and Switzerland, particularly, has expended vast sums in constructing elegant roadways, sometimes carved out of the sheer face of crags overhanging the tumbling torrents below. In two years after automobiles were admitted to these scenic highways, the registrations at tourist hotels doubled in number.

It is no dream to believe that with the construction of good, smooth roads of easy grades in the mountains, through the valleys and along the seashore, the miners' and shepherds' cabins and the fishermen's "shacks" will be displaced in scores and hundreds of picturesque spots by attractive and comfortable modern hostelries. Then, it will be

realized that California made no mistake when she appropriated eighteen million dollars from the public treasury for the laying of the proposed network of highways throughout her communities.

STATE HIGHWAYS.

The State has undertaken to construct and maintain a system of state highways distinct from the state roads elsewhere referred to in this report and has appropriated the sum of $18,000,000 for the purpose.

The state highway act, approved March 22, 1909, outlines in somewhat general terms the scope of the work, the locations of the routes, places the jurisdiction over the proposed state highways in the Department of Engineering, and provides for a bond issue of $18,000,000 and for a state highway fund and a state highway sinking fund. This act was approved by the people at the general election held in November, 1910.

By an act of the legislature in 1911, the Advisory Board of the Department of Engineering was increased to seven members, and the administration of the $18,000,000 highway fund was delegated to three appointed members of the board, designated as the State Highway Commission.

A large force of engineering parties and office employees has been engaged in making surveys, locations and plans for highways, and at the present writing more than six hundred miles of state highways have been constructed under standardized specifications and about four hundred miles additional are under contract or being advertised.

The types of roadway adopted vary according to the conditions encountered, and were selected after careful study of all matters affecting cost, durability and service.

Bridges and culverts of the most substantial character have been introduced, and the design has been made with due regard for ethical considerations.

A summary of the recent operations of the State Highway Commission is presented in the following report, compiled by Mr. George B. Harrison:

SUMMARY OF OPERATIONS OF CALIFORNIA STATE HIGHWAY COMMISSION.

By George B. Harrison.

Construction of the state highways under the act providing the $18,000,000 bond issue has proceeded under the general direction of the California Highway Commission, composed of the three appointed members of the Advisory Board of the Department of Engineering. The plan of the state highways act for principal routes through the Sacramento and San Joaquin valleys and along the coast has been advanced so definitely that the highway commissioners and the highway engineer have been able to give considerable time in 1914 to studies of the secondary routes which the law contemplates to connect the mountain and other county seats

XLIII. Concrete Retaining Wall, State Highway.

not on the through routes. The latter have been studied by personal inspections, and reconnoissances have been made and ordered in advance of consideration of the location surveys.

The main routes have assumed definite position in all parts of California, extending from Crescent City and Eureka on the northern coast to San Francisco and through San Luis Obispo and Santa Barbara to Los Angeles and San Diego, and in the interior from the Oregon line, via Yreka, Redding, Red Bluff and Marysville to Sacramento, thence through Fresno and Bakersfield to Los Angeles. The cities on the west side of the Sacramento Valley, those between the San Joaquin Valley and Santa Cruz, and the principal sections of southern California, also have roads laid out for improvement, with construction already provided for.

One hundred and thirty-six contracts had been initiated by the California Highway Commission up to November 30, 1914, and under them, sections of work have been completed, or were under way, in the following counties: Alameda, Butte, Colusa, Contra Costa, El Dorado, Fresno, Glenn, Humboldt, Imperial, Kern, Los Angeles, Madera, Marin, Mendocino, Merced, Monterey, Napa, Orange, Placer, Riverside, Sacramento, San Benito, San Bernardino, San Diego, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Siskiyou, Solano, Sonoma, Stanislaus, Shasta, Tehama, Tuolumne, Ventura, Yolo and Yuba. Other work of a preliminary nature, such as surveys or reconnoissances, has been ordered by the Highway Commission for all the remaining counties and is to be prosecuted vigorously during 1915.

The following summary shows progress made on the state highways to November 30, 1914:

	Miles
Surveys made and plans in various stages of preparation	2,150
Layouts made (154)	1,164
Contracts advertised or awaiting award	47
Contracts let, including certain day labor work (136)	987
Work completed and accepted	320
Work completed but not yet accepted	300

Of the 987 miles of work under contract a division may be made by types of construction as follows:

Type	Miles
Graded only (to be surfaced under future contracts)	266.0
Macadam with thin bituminous carpet	7.6
Oil macadam	24.4
Cement concrete with thin bituminous top	650.1
Macadam with thick bituminous top	16.5
Cement concrete with thick bituminous top	19.1
Timber and concrete trestle	3.1
Total	986.8

The principal items of the completed work have cost the State approximately as follows on the first 211 miles of highway completed and accepted:

Excavation, regardless of classification	$0 44 per cubic yard.
Concrete, in structures	12 60 per cubic yard.
Concrete, in pavement bases	5 93 per cubic yard.
Asphaltic concrete wearing surfaces, 1½ ins. thick	0 54 per square yard.
Thin bituminous tops, ⅜ to ½ inch thick	0 09 per square yard.

State highway routes thus far established, and the counties through which they pass, are as follows:

Route 1, along the Pacific Coast north of San Francisco Bay, through Marin, Sonoma, Mendocino, Humboldt and Del Norte counties. Length, as surveyed and with surveys ordered, 381.2 miles; completed or under contract, 111.6 miles.

Route 2, along the coast south from San Francisco to San Diego through San Mateo, Santa Clara, San Benito, Monterey, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange and San Diego counties. Length, exclusive of county highway in Los Angeles County as surveyed, 464.6 miles; completed or under construction, 302.3 miles.

Route 3, through the Sacramento Valley, from Sacramento to the California-Oregon boundary line, through Sacramento, Placer, Yuba, Sutter, Butte, Tehama, Shasta and Siskiyou counties. Length, as surveyed, 277.6 miles; completed or under construction, 158.5 miles.

Route 4, through the San Joaquin Valley, from Sacramento to Los Angeles, through Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Kern and Los Angeles counties. Length, as surveyed, 270.8 miles; completed or under construction, 211.1 miles.

Route 5, from the San Joaquin Valley system to Santa Cruz via Oakland and San Jose. Length, as surveyed, 92.2 miles; completed or under construction, 55.7 miles.

Route 6, from Sacramento across the Yolo by-pass to a connection with route 7 near Davis. Length, as surveyed, 14.5 miles; under contract, 3.1 miles.

Route 7, from Tehama Junction to Benicia, connecting the county seats of Glenn, Colusa, Yolo and Solano counties. Length, as surveyed, 151.3 miles; under construction, 93.7 miles.

Route 8, from a connection with Route 1 near Ignacio to a connection with Route 7, either at Benicia or Cordelia, via Napa, through Marin, Sonoma and Napa counties. Length, as surveyed, 26.2 miles; under construction, 4.5 miles.

Route 9, connecting San Bernardino with the main highway system, through Los Angeles and San Bernardino counties. Length as surveyed, 31.8 miles; completed or under construction, 17.9 miles.

Route 10, connecting Hanford with the main route and running to Visalia. Length, as surveyed, 18.5 miles.

Route 11, connecting Placerville with the main route at Sacramento. Length, as surveyed, 29.1 miles; completed or under construction, 18.7 miles.

Route 12, connecting El Centro with the main system at San Diego and running through Imperial and San Diego counties. Length, as far as surveys are completed, 102.5 miles; under construction, 21.4 miles.

Route 13, connecting Sonora with the main system in the San Joaquin Valley through Stanislaus and Tuolumne counties. Length, as surveyed, 49.5 miles; under construction, 10.9 miles.

Route 14, in Contra Costa County. Length, as surveyed, 20.8 miles; under construction, 10.6 miles.

Route 15, connecting Colusa with Route 7 at Williams. Length, 8.5 miles.

Route 16, connecting Lakeport with Route 1 at Hopland. Reconnoissance made.

Route 17, connecting Auburn with the main road in the Sacramento Valley. Length, as surveyed, 15.6 miles.

Route 18, connecting Mariposa with the main system in the San Joaquin Valley at Merced. Surveys in progress. Approximate length, 33.9 miles.

Route 19, connecting Riverside with the main system at Los Angeles. Length, as surveyed, 16.9 miles; completed or under construction 16.3 miles.

Route 20, connecting Weaverville with the main system at Redding. Length, as surveyed, 47.9 miles.

Route 21, from Richvale to Oroville, in Butte. Length, as surveyed, 8.7 miles.

The state highway system comprehends approximately 3,000 miles of improved roads to comply with the law, and of these, 1,800 miles are included in the main routes. These latter are to be paved, while the lateral or feeder roads will be surfaced with gravels or other relatively inexpensive native materials. Construction is governed on the line of the following principal characteristics of the roads built: (1) A right of way not less than 60 feet in width, where it is reasonably obtainable, and as direct between objective points as is consistently possible; (2) gradients not exceeding 7 per cent, even in the mountainous parts of the State; (3) curves as open as possible and in no case of less than 50 feet in radius; (4) as many

culverts of sufficient capacity as are needed to take care of surface and underground water; (5) a traveled way, under ordinary conditions, not less than 21 feet in width, and in the mountains not less than 16 feet wide, with the center paved or surfaced so as to be hard and smooth under all climatic conditions at all times of the year, the width of surfacing to be in general 15 feet; (6) smoothly graded roadsides, reserved for future tree planting.

The policy as to paving was established at the outset in a decision to adopt a type of paving that would accord with the traffic needs of the locality served; instead of a rigid standard, local conditions were met by varying types, thereby saving waste of money through unnecessarily high first cost or great maintenance charges. Three types of pavement are possible under conditions in this State: (1) oil macadam pavement (penetration method); (2) concrete roadway with a relatively thin bituminous wearing surface; (3) concrete roadway with a thick bituminous top of asphaltic concrete.

California is fortunate in its production of paving materials, and this has aided materially in state highway construction. This is especially true of the wearing surfaces, for the vast supply of California oil with an asphaltic base has made possible the adoption successfully of the bituminous coverings for the pavements of the California state highways. The earliest work of this sort laid by the Commission was placed near Fresno, where it has been under constant and heavy traffic for two years with hardly any wear appreciable and with almost no need of attention for repairs. It gives every indication of a life of at least four years before repairs will begin to be necessary.

An experience of more than two years has likewise demonstrated the suitability of a concrete base of four inches in thickness where the subgrade is firm and hard or can be made so and likely to remain so; and in most cases where the traffic is normal, with a daily volume of up to, say, 500 to 600 vehicles, the four-inch cement concrete base with a bituminous top of one half to three eighths inch in thickness is being constructed. If the concrete is laid over adobe or other bad material, the base is thickened to five or six inches. The width of the paving is generally fifteen feet, exclusive of the shoulders. Where the traffic is very great in volume, as on the peninsula south of San Francisco, the paving is made wider, from twenty to twenty-four feet, and the wearing surface is thicker, ordinarily one and one half inches of asphalt or asphaltic concrete.

A maintenance organization for the state highways was initiated in 1914 by the Highway Commission and is being established in all of the seven divisions of the work for the utilization of the money made available in the State's portion of the motor vehicle fund.

MOTOR VEHICLE DIVISION.

By an act passed by the legislature in 1913 (Chapter 326, Statutes 1913), it was made the duty of the Department of Engineering to register all automobiles and motorcycles, their owners or operators and all chauffeurs, and to issue licenses therefor. In short, the administration of the law requiring motor vehicles and their operators to be licensed by the State was placed in the Department of Engineering.

The law was approved May 31st, to go into effect on December 31, 1913.

The fee for motor vehicle licenses imposed by this law varies in amount according to the rated horsepower of the motor or engine, as follows:

For less than 20 horsepower	$5 00
20 to 29 horsepower, inclusive	10 00
30 to 39 horsepower, inclusive	15 00
40 to 49 horsepower, inclusive	20 00
50 to 59 horsepower, inclusive	25 00
60 horsepower and over	30 00

The fee for motorcycles is $2.00 and for chauffeurs' licenses, $2.00.

All licenses must be renewed at the same fee each year. The collection of the fee was delegated to the State Treasurer.

In order to administer the law, a division was organized in the Department of Engineering for the purpose, designated Motor Vehicle Division. Mr. W. R. Ormsby was appointed superintendent of the division, and with a large force of clerks, stenographers and other assistants, installed in the State Capitol.

During the first months after the law became effective but few licenses were issued because actions had been commenced in the courts to test the validity of the act, and until a decision was handed down but few automobile owners applied for licenses.

After the decision of the Supreme Court sustaining the law and until the present writing, about 120,000 automobile and 21,000 motorcycle licenses were issued. With each automobile license is given two number plates, bearing the license number, to be attached to the car. The plates used in 1914 weighed three pounds a pair, and as 123,000 pairs were purchased the weight of the number plates used during the year amounted to 180 tons, or eight carloads of 22½ tons each.

The plates purchased for 1915 are somewhat lighter in weight.

It being impracticable to test the engines of vehicles for which license is desired, the Division accepted the rating placed upon them by the makers.

It was discovered, however, that this rating was not always true. Some makes of engines were found which were actually of greater horsepower than the rating indicated and as this was manifestly unfair to those whose engines were correctly rated, the Department made inquiries to obtain a reasonably correct method of deducing the power of an internal combustion engine from the dimensions of the parts through which it derives its power.

Professor Wm. D. Ennis, member of the American Society of Mechanical Engineers, Professor of Mechanical Engineering at the Polytechnical Institute of Brooklyn, New York, has evolved a formula based upon the thermodynamic principles underlying the generation of power

in an internal combustion cylinder working under the following conditions:

(1) A pre-compression pressure of 12 pounds per square inch, absolute, and a temperature of 200 degrees Fahrenheit.

(2) Compression takes place along a curve, $P.V.^{1.3}$, which equals a constant.

(3) Temperature after compression, 600 degrees Fahrenheit.

(4) Temperature after ignition, 3,000 degrees Fahrenheit.

(5) Expansion along a curve, $P.V.^{1.3}$, a constant.

The formula derived from the foregoing is expressed thus:

$$H.P. = \frac{a\,l\,r}{C} \qquad (1)$$

H.P. = Horsepower.

a = area of cylinder bore in square inches.

l = length of stroke in inches.

r = revolutions of crankshaft per minute.

C = Constant derived from above conditions = 12,620.

The area of a cylinder is found by the equation: $0.7854d^2$, where d = diameter of the bore.

The "piston travel," *i. e.*, the distance the piston travels at each revolution of the crankshaft is twice the length of stroke, and reduced to feet is expressed thus:

$$\frac{2\,l}{12} \quad \text{or} \quad \frac{l}{6} \qquad (2)$$

The "piston speed," (s), in feet per minute is equal to the piston travel multiplied by the number of revolutions per minute, or:

$$s = \frac{l\,r}{6} \qquad (3)$$

Per contra, $l\,r = 6\,s$

The Institute of Automobile Engineers found from actual tests of automobile engine performances that the relation between the piston speed and the cylinder dimensions could be expressed by the formula:

$$s = 600\left(\frac{l}{d} + 1\right) \qquad (4)$$

Since $\frac{l\,r}{6} = s$, and $600\left(\frac{l}{d} + 1\right) = s$, then

$$l\,r = 3600\left(\frac{l}{d} + 1\right) \qquad (4)$$

Substituting this value of l and r in the formula (1) above, in which $H.P. = \frac{a\,l\,r}{C}$ and also substituting for a, its equivalent $0.7854\,d^2$, formula (1) becomes:

$$H.P. = \frac{3600\left(\frac{l}{d} + 1\right)\ 0.7854\,d^2.}{12{,}620} \qquad (5)$$

which in turn can be reduced to several forms, thus:

$$H.P. = 0.224 \left(\frac{l}{d} + 1\right) d^2 \quad (6)$$

$$H.P. = 0.224 \left(\frac{l + d}{d}\right) d^2 \quad (7)$$

$$H.P. = 0.224 \ (l + d) \ d \quad (8)$$

Re-stating the value of the elements of the last formula (8):

H.P. = Horsepower.

l = length of stroke in inches.

d = diameter of cylinder in inches, the rule for computing the horsepower of an automobile engine cylinder is given thus:

Add the stroke and diameter, both expressed in inches; multiply the sum by the diameter, and multiply that product by the decimal 0.224. For example:

What is the horsepower of a four-cylinder automobile engine with a three-inch bore and four-inch stroke?

Taking the formula (8) for one cylinder, H.P. = 0.224 (l + d)d and substituting figures for the letters, it becomes:

$0.224 \times 4 + 3 \times 3 = 0.224 \times 7 \times 3 = 4.704$, which is taken to the nearest tenth, or 4.7. Multiply this result by the number of cylinders, or $4.7 \times 4 = 18.8$ horsepower, as the answer.

Many imported engines have the dimensions expressed by the metric system of notation. In such cases the bore and stroke are given in millimeters, and the formula becomes:

H.P. = 0.000347 (l + d) d

wherein H.P. = horsepower,

l = length of stroke in millimeters,

d = diameter of cylinder in millimeters.

The Department of Engineering adopted the last above stated formula for determining the horsepower of motor vehicles, and the fee for all licenses issued for the current year has been computed by that formula.

Some automobile owners having cars the horsepower of which had been underrated, have made vigorous protests against the new ratings, but the Department submits that the new rates, being based upon a more correct method, are equitable, whereas the old rates were unfair.

The operations of the Motor Vehicle Division for the fiscal year ending June 30, 1914, are set forth in detail in the report of the superintendent, here following:

REPORT OF THE OPERATIONS OF THE MOTOR VEHICLE DIVISION—DEPARTMENT OF ENGINEERING.

By W. R. Ormsby, Superintendent.

In accordance with instructions, there is submitted the following report of the operations of the Motor Vehicle Division of the State Department of Engineering, for the period beginning August, 1913, and terminating with June 2, 1914. This period is indicated because

the motor vehicle act requires that semiannual reports shall be made by the State Department of Engineering to the State Controller as of January 1st and July 1st of each year, therefore, a financial report for the second period of the year 1914 can not be made.

As the State Treasurer could not close his books for the first period ending with June 30, 1914, because of pending adjustments, the figures which follow show receipt of moneys to and including June 2d, while the expenditures shown are to and including June 30th.

Total receipts	$1,179,986 75
Total expenditures	114,421 00
Net receipts	$1,056,565 75

The apportionment of the net receipts in accordance with the motor vehicle act, to the counties, was made as shown by the following statement:

TABLE No. 48.
County Apportionment of Motor Vehicle Receipts.

County	Gross cash receipts to June 2, 1914	Administration and operating expenses to July 1, 1914	Net cash receipts to June 2, 1914	Amount due counties	Amount due State of California
Alameda	$80,964 00	$7,911 23	$73,052 77	$36,526 38	$36,526 39
Alpine	25 00	2 44	22 56	11 28	11 28
Amador	1,473 50	144 00	1,329 50	664 75	664 75
Butte	9,642 50	942 20	8,700 30	4,350 15	4,350 15
Calaveras	1,387 00	135 55	1,251 45	625 72	625 73
Colusa	3,911 50	382 20	3,529 30	1,764 65	1,764 65
Contra Costa	8,507 75	831 35	7,676 40	3,838 20	3,838 20
Del Norte	478 00	46 70	431 30	215 65	215 65
El Dorado	1,339 00	130 85	1,208 15	604 07	604 07
Fresno	43,213 00	4,222 50	38,990 50	19,495 25	19,495 25
Glenn	4,525 00	442 15	4,082 85	2,041 42	2,041 43
Humboldt	10,234 00	1,000 00	9,234 00	4,617 00	4,617 00
Imperial	13,414 75	1,310 80	12,103 95	6,051 97	6,051 98
Inyo	1,702 75	166 40	1,536 35	768 17	768 18
Kern	22,344 25	2,183 35	20,160 90	10,080 45	10,080 45
Kings	7,908 00	772 75	7,135 25	3,567 62	3,567 63
Lake	1,552 00	151 65	1,400 35	700 17	700 18
Lassen	1,415 50	138 35	1,277 15	638 57	638 58
Los Angeles	402,800 50	39,304 70	363 495 80	181,747 90	181,747 90
Madera	3,115 00	304 40	2,810 60	1,405 30	1,405 30
Marin	6,022 50	588 50	5,434 00	2,717 00	2,717 00
Mariposa	397 00	38 80	358 20	179 10	179 10
Mendocino	4,191 00	409 52	3,781 48	1,890 74	1,890 74
Merced	5,801 00	566 85	5,234 15	2,617 07	2,617 08
Modoc	1,263 00	123 41	1,139 59	569 79	569 80
Mono	92 00	9 00	83 00	41 50	41 50
Monterey	8,205 50	801 78	7,403 72	3,701 86	3,701 86
Napa	6,739 00	658 49	6,080 51	3,040 25	3,040 26
Nevada	1,394 50	136 26	1,258 24	629 12	629 12
Orange	34,930 25	3,413 14	31,517 11	15,758 55	15,758 56
Placer	3,972 50	388 16	3,584 34	1,792 17	1,792 17
Plumas	726 00	70 94	655 06	327 53	327 53
Riverside	19,275 00	1,883 42	17,391 58	8,695 79	8,695 79
Sacramento	32,492 75	3,174 93	29,317 79	14,658 89	14,658 90
San Benito	3,107 75	303 67	2,804 08	1,402 04	1,402 04
San Bernardino	30,300 00	2,960 70	27,339 30	13,669 65	13,669 65
San Diego	54,479 75	5,323 38	49,156 37	24,578 18	24,578 19
San Francisco	122,588 25	11,978 50	110,609 75	55,304 87	55,304 88
San Joaquin	26,446 25	2,584 14	23,862 11	11,931 05	11,931 06
San Luis Obispo	5,892 75	575 80	5,316 95	2,658 47	2,658 48

TABLE No. 48—Continued.

County Apportionment of Motor Vehicle Receipts—Continued.

County	Gross cash receipts to June 2, 1914	Administration and operating expenses to July 1, 1914	Net cash receipts to June 2, 1914	Amount due counties	Amount due State of California
San Mateo	11,529 25	1,126 56	10,402 69	5,201 34	5,201 35
Santa Barbara	16,741 50	1,635 86	15,105 64	7,552 82	7,552 82
Santa Clara	38,538 75	3,765 74	34,773 01	17,386 50	17,386 51
Santa Cruz	9,159 50	895 00	8,264 50	4,132 25	4,132 25
Shasta	3,096 50	302 57	2,793 93	1,396 96	1,396 97
Sierra	582 00	56 87	525 13	232 56	232 57
Siskiyou	3,275 00	320 01	2,954 99	1,477 49	1,477 50
Solano	8,556 75	836 10	7,720 65	3,860 32	3,860 33
Sonoma	18,906 25	1,847 39	17,058 86	8,529 43	8,529 43
Stanislaus	16,656 25	1,627 55	15,028 70	7,514 35	7,514 35
Sutter	2,948 50	288 11	2,660 39	1,330 19	1,330 20
Tehama	3,959 00	386 84	3,572 16	1,786 08	1,786 08
Trinity	198 00	19 35	178 65	89 32	89 33
Tulare	23,120 75	2,259 20	20,861 55	10,430 77	10,430 78
Tuolumne	2,000 00	195 42	1,804 58	902 29	902 29
Ventura	12,638 25	1,234 95	11,403 30	5,701 65	5,701 65
Yolo	7,828 25	764 92	7,063 33	3,531 66	3,531 67
Yuba	2,922 50	285 57	2,636 93	1,318 46	1,318 47
Totals	$1,170,986 75	$114,421 00	$1,056,565 75	$528,282 73	$528,283 72

The experience had in the administration of the law during the present year has shown the advisability of making minor changes in the law looking to greater efficiency, which have been submitted in the form of memoranda. Should these amendments be adopted by the coming legislature, it will assist materially in the enforcement of the law.

As approximately fifty per cent of the entire registrations of the State were made from the following named counties, San Diego, Imperial, Orange, Riverside, San Bernardino, Los Angeles, Santa Barbara, Ventura, San Luis Obispo, Kern, Inyo and Mono, it was deemed advisable for the accommodation of the residents of these counties, and to relieve the enormous congestion at the Sacramento office at the busy period of the year, to wit: December and January, to establish a branch office in the city of Los Angeles, which has been done. While, of course, it increases the expenses of the department, the increase is more than compensated for by the greater efficiency of the work, and after the period of great rush in the above mentioned months, the expenses will be reduced to the minimum. The cost of maintaining it is inconsiderable as compared with its value to the public of those counties it is intended to serve. The records are kept at the office of the Division in the State Capitol.

For the purpose of an analysis of the expenditures of the Division for the same period as the receipts shown, to wit: to June 2, 1914, the expenditures are given as $100.528.48. This expenditure is made up of the following items and against each is shown the per cent it bears to the receipts for license fees:

TABLE No. 49.

Cost of Operation of Motor Vehicle Division (Including Treasurer's Division) for the Period August 10, 1913, to May 31, 1914.

	Pay rolls	Expenses	Stamps	Typewriters	Express	Printing	Furniture, etc.	Plates, seals and badges	Total
August, 1913	$73 33			$81 00		$4 20			$158 53
September, 1913	445 00	$64 82							509 82
October, 1913	450 00	58 00	$60 00			902 21			1,470 29
November, 1913	1,151 33	6 30	1,400 00	41 50	$58 93	1,150 87	$1 45	$5,500 22	9,290 60
December, 1913	2,254 09	90 00	300 00	41 50	27 43	899 38		19,836 96	23,448 36
January, 1914	6,016 10	507 83	924 00	49 00	73 16	265 66	50 50	9,464 27	17,350 52
February, 1914	4,473 28	338 85	470 00	103 50	25 40	713 98	968 62	14,072 08	21,165 71
March, 1914	6,811 53	486 53	2,279 47	352 00	42 97	1,275 91	135 43	167 96	11,541 80
April, 1914	3,614 00	204 01	448 60	49 10	7 54	1,478 61	27 60	15 30	5,844 76
May, 1914	2,802 05	216 92	366 76	438 50	100 00	5,717 73	90 55	15 58	9,748 09
Totals	$28,090 71	$1,973 34	$6,248 83	$1,156 10	$315 43	$12,408 55	$1,264 15	$49,071 37	$100,528 48
Per cent of revenue	02.41	00.16	00.53	00.10	00.03	01.06	00.11	04.19	08.59

APPENDIX.

STATEMENT OF FINANCIAL TRANSACTIONS

In relation to work executed at state institutions by the Department of Engineering.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
State Roads.			
Alpine State Highway (Ch. 468, 1911):			
Balance	$6,817 85		
Expended		$6,815 43	
Balance			$2 42
Alpine State Highway (Ch. 120, 1913):			
Appropriation	6,000 00		
Expended		5,996 11	
Balance			3 89
California Redwood Park Road (Ch. 398, 1913):			
Appropriation	70,000 00		
Expended		3,966 00	
Balance			66,034 00
Emigrant Gap Road (Ch. 121, 1913):			
Appropriation	1,000 00		
Expended		999 93	
Balance			07
Emigrant Gap Road (Ch. 680, 1913):			
Appropriation	8,000 00		
Expended		6,305 85	
Balance			1,694 15
Emigrant Gap Road; change in location (Ch. 619, 1913):			
Appropriation	4,000 00		
Expended		3,973 15	
Balance			26 85
Emigrant Gap Road (Ch. 503, 1911):			
Balance	379 20		
Expended		379 20	
Balance			0 00
Kings River Road (Ch. 502, 1911):			
Balance	4,277 37		
Expended		3,746 07	
Balance			531 30
Kings River Road (Ch. 680, 1913):			
Appropriation	4,000 00		
Expended		1,662 80	
Balance			2,337 20
Lake Tahoe Road (Ch. 117, 1913):			
Appropriation	3,000 00		
Expended		2,996 06	
Balance			94
Lake Tahoe Road (Ch. 680, 1913):			
Appropriation	15,000 00		
Expended		10,964 42	
Balance			4,035 58
Lake Tahoe Road (Ch. 334, 1911):			
Balance	146 53		
Expended		143 75	
Balance			2 78
Lake Tahoe Road (Ch. 705, 1911):			
Balance	2,339 59		
Expended		2,339.15	
Balance			44

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
State Roads—Continued.			
Meyers-McKinneys State Highway, allotted by United States Forest Service:			
Appropriation	500 00		
Expended		499 81	
Balance			19
Meyers-McKinneys State Highway (Ch. 158, 1911):			
Balance	3,230 21		
Expended		3,229 61	
Balance			60
Meyers-McKinneys State Highway (Ch. 453, 1913):			
Appropriation	19,168 76		
Expended		19,168 76	
Balance			0 00
Meyers-McKinneys State Highway (Ch. 119, 1913):			
Appropriation	2,000 00		
Expended		1,996 61	
Balance			3 39
Meyers-McKinneys State Highway (Ch. 423, 1913):			
Appropriation	23,000 00		
Expended		23,000 00	
Balance			0 00
Lassen State Highway (Ch. 468, 1911):			
Balance appropriation	1,951 99		
Expended		1,815 03	
Balance			136 96
Mono Lake Basin Road (Ch. 705, 1911):			
Balance	2,790 51		
Expended		1,660 35	
Balance			1,130 16
Mono Lake Basin Road (Ch. 680, 1913):			
Appropriation	5,000 00		
Expended		4,159 03	
Balance			840 97
Sonora and Mono Road (Ch. 705, 1911):			
Balance	1,765 98		
Expended		1,739 49	
Balance			26 49
Sonora and Mono Road (Ch. 150, 1905):			
Balance	54 58		
Expended		52 50	
Balance			2 08
Sonora and Mono Road. Appropriation from Emergency Fund, Board of Control (Ch. 680, 1913):			
Appropriation	500 00		
Expended		500 00	
Balance			0 00
Sonora and Mono Road (Ch. 561, 1909):			
Balance	3,993 69		
Expended		3,986 96	
Balance			6 73

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
State Roads—Continued.			
Sierra and Downieville Road (Ch. 116, 1907):			
Balance appropriation	98 92		
Expended		12 15	
Balance			86 77
Trinity and Humboldt Highway (Ch. 274, 1911):			
Construction balance	907 43		
Expended		904 50	
Balance			2 93
Trinity and Humboldt Highway—construction (Ch. 106, 1913):			
Appropriation	50,075 22		
Expended		50,075 22	
Balance			0 00
Trinity and Humboldt Highway (Ch. 118, 1913):			
Appropriation	10,000 00		
Expended		5,050 46	
Balance			4,949 54
Trinity, Tehama and Shasta Roads—survey (Ch. 609, 1913):			
Appropriation	3,000 00		
Expended		2,740 78	
Balance			259 22

Statement of financial transaction in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance November 1, 1912, and appropriations	Expended	Balance in fund
State roads.			
Road maintenance (Motor Vehicle Fund, Ch. 326, 1913):			
Overhead expense	$2,500 00	$1,329 52	$1,170 48
Alpine State Highway	33,000 00	20,791 54	12,208 46
Emigrant Gap Road	8,200 00	6,951 97	1,248 03
Lake Tahoe Road	9,000 00	6,523 38	2,476 62
Lassen State Highway	2,000 00	830 00	1,170 00
Meyers-McKinney State Highway	13,000 00	8,461 84	4,538 16
Mono Lake Basin Road	5,000 00	4,231 42	768 58
Sonora and Mono Road	8,500 00	5,233 01	3,266 99
Trinity and Humboldt Road	22,200 00	18,858 91	3,341 09

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Rectifying River Channels.			
(Ch. 465, 1913)			
Appropriation	150,000 00		
Expended		21,112 80	
Balance			128,887 20
(Ch. 551, 1911)			
Balance	193,119 12		
Expended		126,586 00	
Balance			66,533 12
Sacramento River Flood Control.			
(Ch. 25, 1911)			
Balance	8,520 66		
Expended		8,490 80	
Balance			29 86
Appropriation (Ch. 170, 1913)	20,000 00		
Expended, records Department of Engineering		6,794 19	
For balance of expenditures see "Reclamation Board" records.			
Humboldt Bay Survey.			
(Ch. 503, 1909)			
Balance	499 46		
Expended		0 00	
Balance			499 46
Restraining Débris.			
(Ch. 14, 1901)			
Balance	54,543 72		
Expended		3,702 87	
Balance			50,840 85
Eel River Bank Protection.			
(Ch. 502, 1911)			
Balance	12,425 69		
Expended		11,830 01	
Balance			595 68
Mad River Bank Protection.			
(Ch. 526, 1911):			
Balance	15,000 00		
Expended		0 00	
Balance			15,000 00
Canals and Canalization of Rivers.			
(Ch. 742, 1911):			
Appropriation	2,500 00		
Expended		2,496 53	
Balance			3 47
Agricultural Park.			
Dairy Building and Barns (Ch. 534, 1911):			
Balance	3,578 05		
Expended		2,785 72	
Balance			792 33
Grandstand (Ch. 532, 1911):			
Balance	77 78		
Expended		13 56	
Balance			54 22

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
State Fair Grounds.			
Machinery Hall (Ch. 71, 1909):			
Balance	790 14		
Expended		396 51	
Balance			393 63
Grandstand (Ch. 532, 1911):			
Balance	77 78		
Expended		13 56	
Balance			64 22
Manufacturers' Pavilion (Ch. 531, 1911):			
Balance	881 21		
Expended		278 85	
Balance			602 36
Improvements to grounds (Ch. 535, 1911):			
Balance	270 38		
Expended		80 46	
Balance			189 82
Barns, sheds, poultry buildings (Ch. 443, 1913):			
Appropriation	15,000 00		
Expended		1,013 93	
Balance			13,986 07
Drainage and sewerage (Ch. 512, 1913):			
Appropriation	10,000 00		
Expended		4,668 49	
Balance			5,331 51
Armory—Los Angeles.			
Balance (Ch. 408, 1909; 362, 1911)	195,878 50		
(Ch. 468, 1913)	7,000 00		
Expended		197,550 33	
Balance			5,328 17
Armory—Sacramento.			
Balance (Ch. 566, 1911)	93,980 17		
Appropriation (Ch. 469, 1913)	5,000 00		
Expended		96,659 58	
Balance			2,320 59
Armory—San Francisco.			
Balance (Ch. 379, 1909)	342,917 03		
Appropriation (Ch. 549, 1913)	7,000 00		
Expended		345,557 67	
Balance			14,359 36
State Training School for Girls.			
(Ch. 401, 1913)	200,000 00		
Expended by this department		29,244 28	
Balance			170,755 72
California Polytechnic.			
(Ch. 516, 1909):			
Balance	10 05		
Expended		10 00	
Balance			05
Barns (Ch. 511, 1909):			
Balance	211 57		
Expended		187 35	
Balance			24 22
Dining hall (Ch. 207, 1911):			
Balance	298 73		
Expended		141 59	
Balance			157 14

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
California Polytechnic—Continued.			
Water supply:			
Balance (Ch. 504, 1909)	1 98		
Expended		1 98	
Balance			0 00
Heating system (Ch. 493, 1913):			
Appropriation	4,000 00		
Expended		4,000 00	
Balance			0 00
Power, heat and light (Ch. 270, 1911):			
Balance	10 21		
Expended		0 00	
Balance			10 21
Repairs (Ch. 548, 1911):			
Balance	2 63		
Expended		0 00	
Balance			2 63
Repairs (Ch. 492, 1913):			
Appropriation	10,000 00		
Expended		9,853 51	
Balance			146 49
Water system (Ch. 102, 1913):			
Appropriation	5,000 00		
Expended		4,085 09	
Balance			914 91
Water and sewer system (Ch. 228, 1911):			
Balance	1,025 85		
Expended		1,002 66	
Balance			23 19
Chico Normal School.			
Heating plant (Ch. 48, 1911):			
Balance	58 07		
Expended		58 07	
Balance			0 00
Covered passageway (Ch. 136, 1911):			
Balance	140 83		
Expended		115 52	
Balance			25 31
Repairs (Ch. 173, 1913):			
Appropriation	5,700 00		
Expended		4,405 45	
Balance			1,294 55
Repairs and furnishing (Ch. 460, 1913):			
Appropriation	12,870 00		
Expended		12,243 32	
Balance			526 68
Water supply (Ch. 459, 1913):			
Appropriation	3,350 00		
Expended		1,590 59	
Balance			1,759 41
Street work (Ch. 436, 1913):			
Appropriation	4,300 00		
Expended		4,224 30	
Balance			75 70

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Fresno Normal School.			
(Ch. 504, 1911):			
Balance	6,124 24		
Expended		1,571 02	
Balance			4,553 22
Temporary buildings (Ch. 171, 1913):			
Appropriation	10,000 00		
Expended		9,874 88	
Balance			125 12
Contingent, estimated for $1,200	1,200 00		
Expended		1,190 11	
Balance			9 89
Building and equipment (Ch. 516, 1913):			
Appropriation	370,000 00		
Expended		6,556 67	
Balance			363,443 33
Los Angeles Normal School.			
Building and improvement fund (Ch. 79, 1907; 416, 1911):			
Appropriation	700,000 00		
Expended		643,165 16	
Balance			56,834 84
Bleacher and playground equipment (Ch. 504, 1913):			
Appropriation	2,500 00		
Expended		2,303 05	
Balance			196 95
Repairs and improvements (Ch. 303, 1911):			
Balance	2,733 51		
Expended		376 77	
Balance			2,356 74
Preston School of Industry.			
Two cottages (Ch. 156, 1909):			
Balance	10,016 78		
Expended		8,294 59	
Balance			1,722 19
Refectory (Ch. 155, 1909):			
Balance	41 53		
Expended		41 53	
Balance			0 00
Preston School of Industry (Ch. 172, 1913):			
Appropriation	23,000 00		
Expended		2,391 78	
Balance			20,608 22
Hospital equipment (Ch. 529, 1913)	12,000 00		
Expended		8 29	
Balance			11,991 71
Concrete floor (Ch. 549, 1911):			
Balance	1,168 57		
Expended		466 11	
Balance			702 43
Repairs (Ch. 528, 1913):			
Appropriation	18,100 00		
Expended		5,562 30	
Balance			12,537 70

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Preston School of Industry—Continued.			
Repairs (Ch. 680, 1911):			
Balance	3,667 52		
Expended		3,621 86	
Balance			45 66
Pipe line (Ch. 522, 1909):			
Balance	2 21		
Expended		0 00	
Balance			2 21
Trades building (Ch. 531, 1913):			
Appropriation	12,000 00		
Expended		132 59	
Balance			11,867 41
Water system (Ch. 195, 1911):			
Balance	1,043 09		
Expended		643 10	
Balance			399 99
Water power plant (Ch. 206, 1911):			
Balance	4,131 20		
Expended		1,849 46	
Balance			2,281 74
San Diego Normal School.			
Improvements to grounds (Ch. 491, 1913):			
Appropriation	5,000 00		
Expended		4,934 61	
Balance			65 39
Heating plant (Ch. 524, 1913):			
Balance	114 36		
Expended		95 37	
Balance			18 99
Repairs (Ch. 490, 1913):			
Appropriation	12,000 00		
Expended		11,543 76	
Balance			456 24
San Francisco Normal School.			
Painting (Ch. 127, 1909):			
Balance	39 86		
Expended		39 86	
Balance			0 00
(Ch. 421, 1913):			
Appropriation	2,000 00		
Expended		1,461 52	
Balance			538 48
Repainting (Ch. 420, 1913):			
Appropriation	1,800 00		
Expended		1,800 00	
Balance			0 00
San Jose Normal School.			
Grounds (Ch. 193, 1911):			
Balance	140 64		
Expended		2 21	
Balance			138 43
Training building (Ch. 192, 1911):			
Balance	705 66		
Expended		705 59	
Balance			07

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
San Jose Normal School—Continued.			
Reconstruction (Ch. 216, 1909):			
Balance	233 83		
Expended		233 83	
Balance			0 00
Gymnasium (Ch. 463, 1913):			
Appropriation	5,000 00		
Expended		4,986 78	
Balance			13 22
Repairs (Ch. 426, 1913):			
Appropriation	12,000 00		
Expended		11,826 30	
Balance			173 70
Santa Barbara Normal School.			
Grounds (Ch. 535, 1911):			
Balance	4,947 64		
Expended		4,947 64	
Balance			0 00
Main building (Ch. 546, 1911):			
Balance	93,789 14		
Expended		93,506 05	
Balance			283 09
Lunch room (Ch. 547, 1911):			
Balance	8,879 85		
Expended		8,874 96	
Balance			4 89
Sewers (Ch. 495, 1913):			
Appropriation	500 00		
Expended		500 00	
Balance			0 00
Whittier State School.			
Cottage (Ch. 166, 1911):			
Balance	9,986 10		
Expended		21 41	
Balance			9,964 69
Dairy barn (Ch. 233, 1911):			
Balance	3,991 67		
Expended		3,896 69	
Balance			94 98
Electric light plant (Ch. 169, 1911):			
Balance appropriation	3,000 00		
Expended		0 00	
Balance			3,000 00
Manual training building (Ch. 194, 1909):			
Balance	4,218 29		
Expended		3,297 36	
Balance			920 93
Repairs (Ch. 167, 1911):			
Balance	104 98		
Expended		104 98	
Balance			0 00
Cottage (Ch. 485, 1909):			
Balance	1,344 27		
Expended		1,344 27	
Balance			0 00

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Whittier State School—Continued.			
General repairs (Ch. 427, 1913):			
Total appropriation	50,000 00		
Equipment	10,300 00		
Net appropriation	39,700 00		
Expended		37,684 06	
Balance			2,015 94
Repiping (Ch. 232, 1911):			
Balance	860 26		
Expended		88 54	
Balance			771 72
California School for the Deaf and the Blind (Berkeley).			
Dairy barn (Ch. 442, 1913):			
Appropriation	6,000 00		
Expended		2,850 76	
Balance			3,149 24
Fire escapes (Ch. 439, 1913):			
Appropriation	6,500 00		
Expended		6,500 00	
Balance			0 00
Gymnasium (Ch. 440, 1913):			
Appropriation	52,500 00		
Expended		48,314 40	
Balance			4,185 60
Manual arts building (Ch. 655, 1911):			
Balance	51,515 13		
Expended		39,323 90	
Balance			12,191 23
Repairs and improvements (Ch. 514, 1913):			
Appropriation	4,500 00		
Expended		4,159 57	
Balance			340 43
Improvements (Ch. 569, 1909):			
Balance	73 19		
Expended		70 55	
Balance			2 64
Water supply (Ch. 523, 1911):			
Balance	3,997 40		
Expended		3,992 40	
Balance			5 00
Industrial Home of Mechanical Trades for Adult Blind (Oakland).			
Dormitory (Ch. 418, 1913):			
Appropriation	50,000 00		
Expended		18,940 45	
Balance			31,059 55
Floors (Ch. 419, 1913):			
Appropriation	1,500 00		
Expended		1,397 32	
Balance			102 68

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Sonoma State Home.			
Cold storage (Ch. 567, 1909):			
Balance	47 57		
Expended		47 57	
Balance			0 00
Cottage for epileptics (Ch. 508, 1913):			
Appropriation	19,000 00		
Expended		1,138 25	
Balance			17,861 75
Dormitory (Ch. 435, 1913):			
Appropriation	5,000 00		
Expended		220 02	
Balance			4,779 98
Building for farm hands (Ch. 509, 1913):			
Appropriation	2,000 00		
Expended		1,774 70	
Balance			225 30
Nursery for males (Ch. 436, 1913):			
Appropriation	19,000 00		
Expended		14,892 01	
Balance			4,107 99
Power house and boilers (Ch. 568, 1909):			
Balance	177 79		
Expended		125 13	
Balance			52 66
Reflooring (Ch. 519, 1911):			
Balance	2,737 52		
Expended		2,014 18	
Balance			723 34
Manor house (Ch. 448, 1909):			
Balance	18 73		
Expended		0 00	
Balance			18 73
Septic tanks (Ch. 434, 1913):			
Appropriation	5,500 00		
Expended		3,526 24	
Balance			1,973 76
Water supply (Ch. 239, 1911):			
Balance	93 35		
Expended		65 75	
Balance			27 60
Water supply (Ch. 433, 1913):			
Appropriation	10,000 00		
Expended		721 59	
Balance			9,278 41
Contingent estimate No. 1663, 1913—Concrete conduit	2,500 00		
Expended		108 18	
Balance			2,391 82
Contingent estimate No. 778, 1913—Water purifier and storage tank	1,800 00		
Expended		1,324 96	
Balance			475 04
Contingent estimate No. 1287, 1913—Electrical apparatus	145 00		
Expended		137 32	
Balance			7 68
Contingent estimate No. 1264, 1914—Boiler for power house	3,250 00		
Expended		3,070 17	
Balance			179 83

Statement of financial transactions, in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Veterans' Home.			
Oil tank (Ch. 301, 1911):			
Balance	148 35		
Expended		148 35	
Balance			0 00
Amusement, assembly and library building (Ch. 483, 1913):			
Appropriation	15,000 00		
Expended		29 76	
Balance			14,970 24
Cold storage (Ch. 235, 1911):			
Balance	61		
Credit	31 10		
Expended		0 00	
Balance			31 71
Cottage C (Ch. 511, 1911):			
Balance	2,466 67		
Expended		674 57	
Balance			1,792 10
Dairy and cow barns (Ch. 484, 1913):			
Appropriation	7,500 00		
Expended		7,190 01	
Balance			309 99
Water distilling plant (Ch. 252, 1909):			
Balance	953 30		
Expended		873 48	
Balance			79 82
Fire escapes (Ch. 236, 1911):			
Balance	1,135 50		
Expended		879 87	
Balance			255 63
Grounds and appurtenances (Ch. 508, 1911):			
Balance	2,740 77		
Expended		2,616 95	
Balance			123 82
Addition to hospital (Ch. 486, 1909):			
Balance	70 95		
Expended		3 75	
Balance			67 20
Lavatories (Ch. 409, 1913):			
Appropriation	1,250 00		
Expended		1,225 35	
Balance			24 65
Painting (Ch. 410, 1913):			
Appropriation	7,500 00		
Expended		3,149 01	
Balance			4,350 99
Pipe line (Ch. 470, 1913):			
Appropriation	12,000 00		
Expended		11,022 49	
Balance			977 51
Repairs to plumbing (Ch. 482, 1913):			
Appropriation	5,000 00		
Expended		26 20	
Balance			4,973 80
Plumbing (Ch. 507, 1911):			
Appropriation	1,000 00		
Expended		0 00	
Balance			1,000 00

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Veterans' Home—Continued.			
Repairs to buildings (Ch. 508, 1909):			
Balance	72 68		
Expended		65 96	
Balance			6 72
Repairs to buildings (Ch. 411, 1913):			
Appropriation	13,500 00		
Expended		11,608 16	
Balance			1,891 84
Repairs to buildings (Ch. 509, 1911):			
Appropriation	1,000 00		
Expended		32 01	
Balance			967 99
Storehouse and commissary (Ch. 488, 1909):			
Balance	224 59		
Expended		52 50	
Balance			172 09
Septic tanks (Ch. 521, 1911):			
Balance	6,495 36		
Expended		5,372 71	
Balance			1,122 65
Surgeon's residence (Ch. 510, 1911):			
Balance	1,926 55		
Expended		1,860 48	
Balance			66 07
General fund, to complete surgeon's residence, estimate	1,622 25		
Expended		1,398 90	
Balance			223 35
General fund, addition to dining-room:			
Balance, estimate	1,278 26		
Expended		1,096 16	
Balance			182 10
General fund, addition to power house:			
Balance, estimate	1,917 80		
Expended		1,766 72	
Balance			151 08
General fund, cold storage:			
Balance, estimate	778 50		
Expended		637 18	
Balance			141 32
Agnews State Hospital.			
Reconstruction (Ch. 465, 1909, and 528, 1911):			
Balance	113,490 83		
Expended		112,375 06	
Balance			1,115 77
Workers' cottage (Ch. 400, 1913):			
Appropriated	60,000 00		
Expended		18,535 13	
Balance			41,464 87
Nurses' home (Ch. 473, 1913):			
Appropriated	50,000 00		
Expended		7,299 41	
Balance			42,700 59
Wiring conduits and repairing steam lines (Ch. 606, 1913):			
Appropriation	30,000 00		
Expended		27,963 27	
Balance			2,036 73

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Agnews State Hospital—Continued.			
Miscellaneous repairs—Contingent estimate No. 546:			
Balance	1,590 70		
Expended		1,583 75	
Balance			6 95
Installing one 250 horsepower boiler:			
Contingent estimate No. 727, 1914	6,000 00		
Expended		5,954 73	
Balance			45 27
Improvement of heating system and cooperage:			
Contingent estimate Nos. 706 and 945, 1913	3,650 00		
Expended		3,641 43	
Balance			8 57
Gas holder:			
Contingent estimates Nos. 663, 761 and 1203, 1913	6,675 00		
Expended		6,516 11	
Balance			158 89
Repairs to fan heating system:			
Contingent estimate No. 946, 1913	1,500 00		
Expended		1,470 37	
Balance			29 63
Motion picture room:			
Contingent estimate No. 1022, 1913	551 50		
Expended		551 50	
Balance			0 00
Temporary barracks:			
Contingent estimates Nos. 82 and 199, 1914	33,000 00		
Expended		746 97	
Balance			32,253 03
Completion of electric system:			
Contingent estimate No. 92	1,237 50		
Expended		181 50	
Balance			1,056 00
Folsom State Prison.			
Hospital for criminal insane (Ch. 467, 1909):			
Balance	210 80		
Credit	147 80		
	$358 60		
Expended		358 60	
Balance			0 00
Mendocino State Hospital.			
Plumbing (Ch. 93, 1911):			
Balance	3 11		
Expended		3 11	
Balance			0 00
Addition to kitchen (Ch. 497, 1909):			
Balance	67 80		
Expended		67 80	
Balance			0 00
Gas plant (Ch. 481, 1913):			
Appropriation	10,000 00		
Expended		4,501 40	
Balance			5,498 60

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Mendocino State Hospital—Continued.			
Dam and reservoir (Ch. 149, 1911):			
Balance	4,330 25		
Appropriation (Ch. 107, 1913)	12,500 00		
Total	$16,830 25		
Expended		10,779 85	
Balance			6,050 40
Male cottage (Ch. 125, 1911):			
Balance	14,427 85		
Expended		14,166 03	
Balance			261 82
Assistant physician's residence—Contingent estimate No. 379:			
Balance	421 57		
Expended		23 43	
Balance			398 14
Salary of B. B. Kinkade—Contingent estimate No. 444:			
Balance	75 33		
Expended		0 00	
Balance			75 33
Survey of grounds—Contingent estimate No. 553:			
Balance	91 95		
Expended		56 08	
Balance			35 87
Superintendent's residence—Contingent estimates Nos. 824 and 1267, 1913	8,000 00		
Expended		995 24	
Balance			7,004 76
Labor on gas plant:			
Contingent estimate No. 216, 1914	75 00		
Expended		75 00	
Balance			0 00
Completion of gas plant:			
Contingent estimate No. 103, 1914	549 01		
Expended		534 07	
Balance			14 94
Napa State Hospital.			
Water system (Ch. 316, 1909):			
Balance	59 07		
Expended		58 81	
Balance			26
Steam boilers (Ch. 406, 1913):			
Appropriation	7,000 00		
Expended		6,296 15	
Balance			703 85
Cottages (Dozier and Chambers) (Ch. 407, 1913):			
Appropriation	25,000 00		
Expended		11,732 19	
Balance			13,267 81
Cold storage plant (Ch. 506, 1911):			
Balance	12,164 80		
Expended		12,114 81	
Balance			49 99

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Napa State Hospital—Continued.			
Dairy buildings (Ch. 487, 1913):			
Appropriation	20,000 00		
Expended		6,673 08	
Balance			13,326 92
Dormitories and sheds (Ch. 486, 1913):			
Appropriation	10,000 00		
Expended		4,077 48	
Balance			5,922 52
Female cottage (Ch. 489, 1909):			
Balance	319 48		
Expended		0 00	
Balance			319 48
Steam heating system (Ch. 408, 1913):			
Appropriation	20,000 00		
Expended		18,678 52	
Balance			1,321 48
Irrigation (Ch. 505, 1911):			
Appropriation	10,000 00		
Expended		9,458 01	
Balance			541 99
Kitchen (Ch. 314, 1909):			
Balance	51 99		
Expended		0 00	
Balance			51 99
Laundry (Ch. 405, 1913):			
Appropriation	25,000 00		
Expended		18,287 34	
Balance			6,712 66
North pay cottage (Ch. 404, 1913):			
Appropriation	10,000 00		
Expended		8,006 95	
Balance			1,993 05
Receiving and treatment building (Ch. 315, 1909):			
Balance	72 33		
Expended		37 50	
Balance			34 83
Reclamation of lowlands (Ch. 489, 1913):			
Appropriation	10,000 00		
Expended		6,040 89	
Balance			3,959 11
Rewiring (Ch. 488, 1913):			
Appropriation	15,300 00		
Expended		14,296 26	
Balance			1,003 74
Transformers:			
Contingent estimates Nos. 765 and 805, 1912	2,000 00		
Expended		1,273 98	
Balance			726 02
Porch addition to south pay cottage:			
Contingent estimate No. 709, 1913	1,000 00		
Expended		996 50	
Balance			3 50
Steam system:			
Contingent estimates Nos. 660 and 1466, 1912	7,104 84		
Expended		7,104 84	
Balance			0 00

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Napa State Hospital—Continued.			
Heating system—Contingent estimate No. 175, 1912:			
Balance	1,381 29		
Expended		1,381 29	
Balance			0 00
Plumbing, Ward No. 3—Contingent estimate No. 289:			
Balance	67 52		
Expended		0 00	
Balance			67 52
Two parole cottages—Contingent estimates:			
No. 346, balance	10,221 45		
No. 939	3,000 00		
No. 1045	800 00		
No. 1100	720 00		
	14,741 45		
Expended		14,568 76	
Balance			172 69
Laying out of grounds—Contingent estimates:			
No. 504	60 00		
No. 722	150 00		
	210 00		
Expended		181 69	
Balance			28 31
Cold storage plant:			
Contingent estimate No. 913	750 00		
Expended		740 76	
Balance			9 24
Amusement hall:			
Contingent estimates No. 1463, 51 and 135, 1914	12,850 00		
Expended		11,114 60	
Balance			1,735 40
Phone system:			
Contingent estimate No. 1197	1,000 00		
Expended		982 74	
Balance			17 26
Light and power system:			
Contingent estimate No. 1329	650 00		
Expended		645 21	
Balance			4 79
Power line:			
Contingent estimate No. 1429	50 00		
Expended		31 63	
Balance			18 37
Pipe covering:			
Contingent estimate No. 1618	50 00		
Expended		47 64	
Balance			2 36
Alteration of four hot water storage tanks:			
Contingent estimate No. 1620	441 10		
Expended		358 05	
Balance			83 05

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering--Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Napa State Hospital—Continued.			
Moving pole line:			
Contingent estimate No. 1623	22 00		
Expended		22 00	
Balance			0 00
Heating system:			
Contingent estimate No. 1683	14,455 00		
Expended		4,845 61	
Balance			9,609 39
Southern California State Hospital.			
Male cottage (Ch. 216, 1911):			
Balance	2,532 40		
Expended		2,532 40	
Balance			0 00
Assistant physician's residence (Ch. 461, 1909):			
Balance	167 15		
Expended		164 99	
Balance			2 16
Four cottages (Ch. 477, 1913):			
Appropriation	100,000 00		
Expended		98,869 02	
Balance			1,130 98
Dining hall (Ch. 462, 1909):			
Balance	244 27		
Expended		0 00	
Balance			244 27
Female cottage (Ch. 215, 1911):			
Balance	22,458 33		
Expended		22,456 48	
Balance			1 85
Cottage No. 2, females (Ch. 457, 1909):			
Balance	17 00		
Expended		0 00	
Balance			17 00
Cottage for females (Ch. 459, 1909):			
Balance	50 90		
Expended		0 00	
Balance			50 90
Dairy barns (Ch. 155, 1907):			
Balance	135 10		
Expended		0 00	
Balance			135 10
Laundry (Ch. 496, 1913):			
Appropriated	20,000 00		
Expended		3,369 52	
Balance			16,630 48
Receiving cottages (Ch. 466, 1909):			
Balance	298 04		
Expended		232 40	
Balance			65 64
Power plant (Ch. 281, 1911):			
Balance	29,431 71		
Expended		25,544 16	
Balance			3,887 55
Reservoir (Ch. 497, 1913):			
Appropriation	5,000 00		
Expended		4,793 66	
Balance			206 34

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Southern California State Hospital—Continued.			
Storm drains (Ch. 458, 1909):			
Balance	274 71		
Expended		0 00	
Balance			274 71
Completion of cottage G—Contingent estimate No. 544:			
Balance	659 60		
Expended		659 60	
Balance			0 00
Wiring—Contingent estimates:			
No. 375, balance	209 16		
No. 890	75 00		
	284 16		
Expended		279 37	
Balance			4 79
Screen porches to receiving cottage:			
Contingent estimate No. 453, balance	2,710 61		
Expended		2,710 61	
Balance			0 00
Laying out grounds and buildings:			
Contingent estimate No. 461, balance	192 00		
Expended		192 00	
Balance			0 00
Cottages for physicians:			
Contingent estimate No. 311, balance	7,097 39		
Expended		7,086 59	
Balance			10 80
Porch for cottage E—Contingent estimates:			
No. 454, balance	1,832 24		
Nos. 957 and 1009	800 00		
	2,632 24		
Expended		2,539 99	
Balance			92 25
Porch for cottage F:			
Contingent estimate No. 455, balance	1,775 84		
Expended		1,671 90	
Balance			103 94
Cottage I:			
Contingent estimate No. 456, balance	26,937 17		
Expended		26,444 49	
Balance			492 68
Heating system:			
Contingent estimates Nos. 731, 960, 1079	33,671 17		
Expended		24,611 62	
Balance			9,059 55
Heating system:			
Contingent estimate No. 871	2,300 00		
Expended		1,830 22	
Balance			469 78
Contingent estimate No. 1405	124 21		
Expended		124 21	
Balance			0 00
Cover for reservoir:			
Contingent estimate No. 66	350 00		
Expended		330 85	
Balance			19 15

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Norwalk State Hospital.			
Site and buildings (Ch. 455, 1913):			
Appropriation	250,000 00		
Expended		90,627 07	
Balance			159,372 93
Stockton State Hospital.			
Water system (Ch. 377, 1909):			
Balance	34 21		
Expended		34 21	
Balance			0 00
Dairy building (Ch. 499, 1913):			
Appropriation	20,000 00		
Expended		2,854 48	
Balance			17,145 52
Elevators (Ch. 414, 1913):			
Appropriation	6,000 00		
Expended		2,910 07	
Balance			3,089 93
Fire protection system (Ch. 127, 1911):			
Balance	9,850 62		
Expended		9,385 27	
Balance			465 35
Heating system (Ch. 415, 1913):			
Appropriation	15,000 00		
Expended		14,575 68	
Balance			424 32
Heating system (Ch. 197, 1911):			
Balance	22,983 39		
Expended		22,773 08	
Balance			210 31
Reflooring main building (Ch. 413, 1913):			
Appropriation	15,000 00		
Expended		15,000 00	
Balance			0 00
Sewing room and dormitory (Ch. 126, 1911):			
Balance	1,241 88		
Expended		980 40	
Balance			261 48
Telephone system (Ch. 243, 1909):			
Balance	1 04		
Expended		0 00	
Balance			1 04
Ward 25 (Ch. 416, 1913):			
Appropriation	58,000 00		
Expended		35,880 52	
Balance			22,119 48
Water system (Ch. 129, 1911):			
Balance	955 53		
Credit	53 80		
	1,009 33		
Expended		2 35	
Balance			1,006 98
Completion of fire protection system:			
Contingent estimate No. 1516	585 00		
Expended		540 43	
Balance			44 57

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Stockton State Hospital—Continued.			
Plumbing:			
Contingent estimate No. 410	206 81		
Expended		194 91	
Balance			11 90
Plumbing:			
Contingent estimate No. 612, balance	1,798 75		
Expended		1,785 76	
Balance			12 99
Inspecting sewers:			
Contingent estimate No. 752	21 10		
Expended		21 10	
Balance			0 00
Plumbing, etc.:			
Contingent estimates Nos. 770 and 793	1,585 00		
Expended		1,497 24	
Balance			87 76
Inspection of generating plant:			
Contingent estimate No. 854	25 00		
Expended		11 42	
Balance			13 58
Folsom State Prison.			
Cells and walls (Ch. 184, 1905, and 449, 1913)	135,000 00		
Balance	19,944 67		
	154,944 67		
Expended		59,781 92	
Balance			95,162 75
Construction of dairy and farm building (Ch. 447, 1913)	7,000 00		
Expended		4,484 17	
Balance			2,515 83
Additional houses (Ch. 573, 1909):			
Balance	1,347 75		
Expended		0 00	
Balance			1,347 75
Boilers (Ch. 558, 1909):			
Balance	409 70		
Expended		358 35	
Balance			51 35
Laundry and equipment (Ch. 450, 1913):			
Appropriation	12,000 00		
Expended		2,158 74	
Balance			9,841 26
Repairs (Ch. 448, 1913):			
Appropriation	23,500 00		
Expended		12,813 11	
Balance			10,686 89
Shop buildings and equipment (Ch. 451, 1913):			
Appropriation	33,060 00		
Expended		637 17	
Balance			32,122 83
Warden's residence (Ch. 562, 1909):			
Balance	11,930 60		
Expended		8,020 68	
Balance			3,909 92

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
San Quentin State Prison.			
Cells and walls (Ch. 562, 1911):			
Balance	201,525 73		
Expended		130,280 80	
Balance			71,244 93
Guards' cottages (Ch. 559, 1909):			
Balance	12,639 98		
Expended		9,686 20	
Balance			2,953 78
Los Angeles Expositions Building. (Ch. 699, 1909)			
Balance	113 36		
Expended		113 36	
Balance			0 00
Desert Guide Posts. (Ch. 609, 1905)			
Balance	1,838 83		
Expended		997 38	
Balance			840 45
State Capitol (Grounds, Conservatory). (Ch. 532, 1913)			
Appropriation	3,500 00		
Expended		3,300 83	
Balance			199 17
State Capitol (Building).			
Elevators (Ch. 538, 1913):			
Appropriation	10,000 00		
Expended		7,337 05	
Balance			2,662 95
State Library fund	7,700 00		
Elevator—expended		417 51	
Balance			7,282 49
Painting (Ch. 603, 1913):			
Appropriation	12,000 00		
Expended		6,266 77	
Balance			5,733 23
Mission Solano, Sonoma.			
Restoring (Ch. 322, 1911):			
Balance	273 10		
Expended		169 84	
Balance			103 26
Mission Solano, Sonoma.			
Repairs:			
Appropriation (Ch. 480, 1913)	2,000 00		
Expended		1,017 81	
Balance			982 19

Statement of financial transactions in relation to work executed at state institutions by the Department of Engineering—Continued.

	Balance Nov. 1, 1912, and appropriations	Expended	Balance in fund
Department of Engineering.			
Motor Vehicle Division:			
Appropriation (Ch. 326, 1913)	10,000 00		
Expended		9,552 49	
Balance			447 51
Motor Vehicle Fund:			
Allotted from licenses	160,466 24		
Expended		160,466 24	
Balance			
Filing cases (Ch. 565, 1911):			
Balance	97 62		
Expended		95 05	
Balance			2 57
Department of Engineering.			
Contingent expense (Ch. 705, 1911):			
Balance	5,778 98		
Ch. 40, 1913	2,000 00		
Ch. 680, 1913	25,000 00		
	32,778 98		
Expended		23,766 54	
Balance			9,012 44
Contingent expense (Ch. 524, 1913):			
Appropriation	66 65		
To pay deficiency in appropriation for sixty-second fiscal year—expended		66 65	
Balance			0 00
Contingent expense—printing (Ch. 705, 1911):			
Balance	3,307 90		
Expended		2,352 23	
Balance			955 67
Contingent expense—printing, etc. (Ch. 680, 1913):			
Appropriation	5,000 00		
Expended		2,084 93	
Balance			2,915 07

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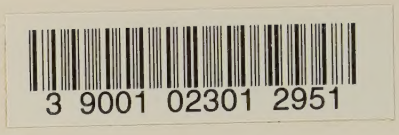
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